Sustainable Minerals Institute

THE UNIVERSITY OF QUEENSLAND
AUSTRALIA
CREATE CHANGE

# Fatigue Management in the Queensland Mining Industry and its relationship with Mental Health

8th November 2022

**Final Report to Office of the Commissioner Resources Safety and Health**

T. Horberry[1], J. Harris[2], K. Way[3], A. Hill[1,3], N. Lim[3], P. Dodshon[1], J. Lee[3] and D. Cliff[1]

[1]MISHC, [2]CSRM, [3]School of Psychology, The University of Queensland

Ranked in the world's top 50, The University of Queensland (UQ) is one of Australia's leading research and teaching institutions. UQ strives for excellence through the creation, preservation, transfer and application of knowledge. For more than a century, we have educated and worked with outstanding people to deliver knowledge leadership for a better world.

The Minerals Industry Safety and Health Centre (MISHC) conducts research in occupational safety and health, risk management and human factors. The results and findings of this research inform the Centre’s postgraduate and continuing education programs and consultancy services. The team has extensive experience conducting research and educational programs in mines across Australia, as well as in Africa, Asia and South America. The team’s expertise covers risk management, occupational health, psychology, physiotherapy, and human factors and ergonomics. MISHC has been supported in this research by staff from the Centre for Social Responsibility in Mining and the School of Psychology.

The project management methodology to be used for this research project is SMI’s Project Management Framework. This is a lifecycle-based approach which provides internal controls to ensure that deliverables are delivered to time, cost and quality specifications. Delivery is managed in accordance to agreed milestones, risks are managed and issues resolved promptly, status is reported internally as well as to the funding sponsor regularly. SMI prides itself on not just delivering technically excellent products that meet your specification, but also delivering this in line with international best practice project management, based on the Project Management Body of Knowledge.

## Executive Summary

This project focused on fatigue, and fatigue management, in Queensland mining. It also examined the relationships between fatigue, safety, and mental health in mining.

A fatigue management baseline was established, this included: (a) a targeted review of current information about fatigue management from regulatory, industry, and academic sources; (b) analysis of incident data to better understand fatigue as a hazard in Australian mining; and (c) a gap analysis to assess the likely effectiveness of existing fatigue management processes at a selection of mine sites. Additional literature reviews in mining then explored the relationships between fatigue, health and safety, and mental health.

From the Queensland data, around 2.5% of all reported notifiable incidents included fatigue as a factor. Across three Australian mining jurisdictions, fatigue related incidents were most frequently reported for heavy vehicle drivers on surface mines. Evidence indicates that characteristics of the task, mitigating controls that alert drivers and supervisors of an incident, and more advanced knowledge about the effect of fatigue on drivers, likely contribute to the higher levels of reporting compared to other jobs.

The work closed by examining the gaps in current Queensland fatigue risk management guidance relative to leading practice. A comparison of the controls from QGN16 and those in more recent guidance documents was presented in bow-tie format. Overall, the changes in the bow-ties across time show a general maturing in the mining industry’s understanding and management of risks associated with fatigue. Whilst it is recognised that the industry has made considerable progress in the area of fatigue management, additional controls based on leading practice elsewhere are possible. These additional controls, which could potentially be incorporated into future versions of a Queensland fatigue risk management guidance note, include a better consideration of mental health outcomes, a greater use of fatigue detection technologies, and addressing the challenges sometimes faced when Queensland workplaces wish to implement fatigue management controls but are complicated by mandated thresholds for agreement in consultation processes.

The conclusions of the work contained in this report are:

1. ***Fatigue Incident Data Collection***: It is highly likely that registered fatigue incident numbers represent under-reporting, so further work to help collect more comprehensive fatigue incident data in Queensland is advised.
2. ***Fatigue Incidents***: Prioritised action plans to focus on fatigue risks for heavy vehicle drivers on surface mines during night shifts are proposed, especially during their first few shifts of the roster cycle.
3. ***Fatigue Management***: It is proposed that the effectiveness of fatigue management controls should be verified, and that controls need to be regularly reviewed. This issue is particularly important given the challenges sometimes faced when Queensland workplaces wish to implement fatigue management controls but are thwarted by mandated thresholds for agreement in consultation processes, so a review of legislation against best practise for continuous improvement is proposed. Additionally, worker consultation was a key area emerging in leading practice, so greater consultation in developing fatigue management and rostering arrangements is advised. Equally, greater use of enhanced lighting interventions in mining fatigue management is advocated. Overall, well-designed studies to evaluate the efficacy of fatigue management interventions in the mining industry are needed.
4. ***Industry Fatigue Management Gaps***: From the mine site document reviews, better monitoring of the long-term health effects of fatigue, a consideration of mental health outcomes, a greater use of fatigue detection technologies (with associated psychological safety and health support systems), and a stronger corporate emphasis of the importance of mining fatigue management are proposed.
5. ***Mental Health and Fatigue***: Further work by the industry in the mental health area is needed, particularly examining fatigue as a mechanism in mental health outcomes, and mental health as a potential predictor of fatigue and health and safety outcomes.
6. ***Mentally Healthy Workplaces Toolkit***: Following other states, it is proposed that a toolkit be developed by government and industry stakeholders to assist workplaces to assess psychosocial hazards and risk as they may relate to fatigue and mental health outcomes. This toolkit could also be used to inform prevention activities as well as being used during incident investigations or during major mine site changes (such as the introduction of automation).

# Contents

# 1. Introduction

This report presents the findings of the project '*Fatigue Management in the Queensland Mining Industry and its relationship with Mental Health'* undertaken by the University of Queensland.

## 1.1 Background

The University of Queensland was engaged by the Commissioner for Resources Safety and Health to undertake an expert examination of fatigue management in the Queensland mining industry and its relationship with mental health and safety outcomes.

## 1.2 Objectives

The work had five objectives:

1. To identify if fatigue remains a hazard in the Queensland mining industry and the extent of fatigue as a hazard.
2. To identify what constitutes good practice in contemporary workplace fatigue management, in mining and similar industries.
3. To establish the current state of fatigue management practices in the Queensland mining industry and focus on any important gaps with the good practice requirements identified in the second objective.
4. To examine the links between worker fatigue, safety and mental health outcomes.
5. To provide a greater understanding of what the Queensland mining industry is doing well and recommend improvement opportunities.

## 1.3 Approach and summary of findings

Part 1A is a targeted review of current regulatory, industry, and academic research information relating to fatigue management. Part 1B is the analysis of incident data and related statistics to assist in understanding fatigue as a hazard in Australian mining. Part 1C is a gap analysis to assess the likely effectiveness of current fatigue management processes. Part 2 is a review of fatigue and outcomes for mental health and safety. Part 3 contains additional analyses and final reporting.

In Part 1A, the fatigue management baseline review found:

- The review of academic research information initially identified over 3,000 papers, which were subsequently reduced to around 50 key articles that met the inclusion criteria and examined different fatigue management strategies applied in the mining domain. The review considers fatigue management intervention studies in categories, such as lighting, rostering and shift design, psychosocial hazards, environmental conditions, fatigue identification or assessment, commuting, training, and combined interventions. By far the greatest number of fatigue management intervention studies focused on rostering and shift design.
- The regulatory review focused on the management of fatigue expressed in Acts, Regulations, Codes and Guidelines. To identify how fatigue is captured across the various legislative documents, a comparison was made of fatigue risk management practices noted across the Model WHS laws, as well as legislation in Queensland, Western Australia, and New South Wales. Then the review compared the various recognised standards / codes of practice in mining from Queensland, Western Australia, New South Wales, international jurisdictions, and from the general health and safety space. Finally, it compared the guidance notes in mining from Queensland and New South Wales, and the general health and safety guidance from SafeWork Australia.
- The industry information review focused on management of fatigue at seven mine sites/organisations. Specifically, it examined the process organisations employed to identify and implement procedural (soft) and practical (hard) controls to manage the risk of fatigue. A leading industry-based taxonomy, was applied to categorise the controls identified in each of the documents.

In Part 1B, an analysis of mining incident data was undertaken to determine how the industry describes fatigue, the job and mine types where fatigue events more commonly occur, and the category of incident, consequence, and controls that typically characterise them. The major purpose of study 1B was to describe and explore those incidences where fatigue was explicitly reported as a contributing factor. We did not undertake more advanced statistical tests to determine whether identified fatigue risk factors (e.g., night shift) significantly affected prevalence of all incidences. Data were analysed for fatigue-reported incidents from Queensland, New South Wales, and Western Australia regulatory agencies, as well as comparison summary data from transport and other workplace incidents.

For example, looking specifically at Queensland data, it was found that over 80% of incidents occurred at coal mines, mostly surface coal mines. Further, over 80% of incidents occurred in vehicles, and most of these were heavy vehicles. Overall, a picture emerged from the results of the location and job type where nearly all of the reported incidents occurred, which was driving heavy vehicles on surface coal mines. When comparing the number of fatigue-reported incidents across years, there was an apparent drop in reported fatigue-related vehicle events in 2020 and 2021 compared to the previous nine years. The reported fatigue-related patterns for NSW and WA were broadly similar to the Queensland data.

In Part 1C, which addresses gaps in fatigue management, the companies who provided information demonstrated that they include the majority of the QGN16's contents in their fatigue risk management systems. While not definite gaps, areas of relative weakness are:

- Processes to monitor longer term health effects from fatigue
- Relatedly, a lack of consideration of mental health outcomes
- Use of technologies for fatigue/awareness
- The level of corporate emphasis on the importance of mining fatigue management

In Part 2, a second review of academic literature was undertaken, this time on relationships between fatigue, health and safety, and mental health within the mining industry. The review synthesised literature in relation to three core questions:

1. What is the relationship between fatigue and health and safety outcomes in the mining industry?
2. What is the relationship between fatigue and worker mental health in the mining industry?
3. Does worker mental health predict fatigue-related safety outcomes in the mining industry?

In conducting this review, 3449 references were initially identified, which were subsequently reduced to 88 key articles that met the inclusion criteria, which were related to fatigue, health and safety, and mental health within the mining industry. These were summarised to answer the three research questions posed as part of this second literature review.

For the first question in part 2, the literature surrounding worker fatigue and health and safety outcomes within the mining industry suggests that work characteristics (such as shift work, environmental conditions, and the requirements for driving heavy vehicles) can lead to circadian disturbances, irregular eating patterns, chronic sleep loss, and poor sleep quality which are predictors of both diagnosable health outcomes (sleep disorders, cardiovascular and gastrointestinal disorders, obesity, metabolic conditions, and impaired cognitive function) and safety outcomes (reduced attention and concentration, risk taking, and work-related errors, violations, and injury outcomes). In relation to patterns of work scheduling, swing shifts were reported to influence factors such as sleep quality, alertness, and circadian rhythm disruption, which can lead to increased fatigue levels in workers. There are conflicting and inconsistent findings regarding shift length. A small number of studies report that psychosocial hazards, exposure to heat and noise, as well as a myriad of individual factors (age, individual health, home environments conducive to good sleep hygiene) can increase fatigue and have adverse health and safety consequences for mine workers. Last, the review identified a number of studies that explored detrimental safety outcomes (vehicle-related accidents, impaired performance) associated with driver fatigue in mining.

For the second research question in part 2, the literature surrounding fatigue or sleep-mediated mental health outcomes within the mining industry was found to be significantly smaller in scale and more limited than studies that explore mental health outcomes predicted by other work characteristics. Nevertheless, studies report the importance of worker autonomy and/or involvement in shift scheduling decisions, rostering to accommodate sufficient sleep and social inclusion/connectedness, negative implications of extended work shifts, and support structures for shift workers in predicting mine workers' mental health. A number of individual-related factors (health, gender, age, and social factors) were reported to influence the relationship between worker fatigue and mental health outcomes in mining.

For the third research question in part 2, it was found that current research specific to the mining industry has not placed much focus on mental health predicting fatigue and safety outcomes. For those that did study this relationship, high fatigue levels, sleep disturbances, and more frequent injuries were found to be consequences of poor mental health of workers.

In part 3, the work analysed fatigue management in Queensland, particularly as expressed in QGN16. This was compared to leading fatigue management practice in other States, in non-mining domains and internationally. Two bow-tie diagrams were created: one examining current fatigue management controls in QGN16, and a second showing leading practice in fatigue management as possible additional controls to QGN16. It is anticipated that this will assist in helping to provide directions for future fatigue management in Queensland, especially regarding better monitoring of the long-term health effects of fatigue, a consideration of mental health outcomes, and a greater use of fatigue detection technologies.

# 2. Part 1A - Fatigue management baseline

Part 1A is a targeted review of information relating to fatigue management. It consists of three components:

i. Academic literature research sources (e.g., journals);

ii. Regulatory and other Government information (e.g., Guidelines, Codes of Practice);

iii. Industry information covering the identification and implementation of procedural (soft) and practical (hard) controls to manage the risk of fatigue.

## 2.1 Academic literature related to fatigue management interventions

Understanding the evidence base related to fatigue management interventions within the mining industry is essential to ensure proper and effective risk management. To further this understanding, a systematic review was conducted to synthesise extant literature in relation to two core questions:

1. What fatigue management interventions are being used in the mining industry?
2. What is the efficacy of the fatigue management interventions being used in the mining industry?

This review is structured around these two research questions and for this review terms are defined as below:

**Mining industry:** For the purposes of this review, organisations in the mining industry are defined as those that mainly extract: naturally occurring mineral solids (i.e., coal and ores); liquid minerals, such as crude petroleum; and gases, such as natural gas. This includes: underground or open cut mining; well operations or evaporation pans; recovery from ore dumps or tailings; beneficiation activities (i.e. preparing, including crushing, screening, washing and flotation) and other preparation work customarily performed at the site. Both mine operation and mining support activities are included. (Definition adapted from the Australian Bureau of Statistics definition of “extractive industries”; ABS, 2013)

**Worker fatigue:** the decreased capability to perform mental or physical work, produced as a function of inadequate sleep (quantity or quality), circadian disruption or time on task (Brown, 1994).

**Fatigue management:** workplace strategies or interventions to identify, assess, control, or review risks associated with worker fatigue (e.g., short naps, bright light, alertness management).

In conducting this review, a systematic search of the literature was conducted using structured search terms and inclusion/exclusion criteria. Four databases were searched to find eligible papers: PubMed, Web of Science, Elsevier via Embase and CINAHL. 3,456 studies were retrieved at the initial search stage. In addition, grey literature and industry reports were sourced.

In the selection phase, duplicate searches were removed using the software applications Endnote and Covidence. This left 2,878 articles that were screened by the research team via title and abstract. Finally, a total of 68 articles related to fatigue management interventions within the mining industry that met the inclusion criteria were summarised for this review. Given that there were a high number of articles specific to mining, transport-related papers were only included if they related directly to the mining industry (e.g., commuting, supply chain etc.).

## Introduction

The focus of this academic literature review is fatigue management interventions in the mining industry. Given the structured and rigorous way this review was conducted, it does not provide an overview of the occupational fatigue literature more broadly, but rather focuses only on the mining industry as defined above.

Work-related fatigue and sleep deficiency remain a critical concern for the health and safety of workers within mining and related industries (Paterson, Ferguson & Dawson, 2020), and studies related to the relationships between fatigue and health and safety outcomes are summarised in an additional literature review outlined in Part 2 of this report. While there is a need for further field studies to evaluate the efficacy of interventions or risk control measures (Cliff, 2006), a wide range of studies have sought to identify and/or evaluate fatigue management interventions used to prevent or mitigate fatigue risk within the mining industry. These are summarised below and categorised by the type of intervention studied (i.e., enhanced lighting, rostering and shift design, psychosocial hazards, environmental conditions, fatigue identification or assessment, commuting, training, and combined interventions).

### 2.1.1 Enhanced Lighting

Bright light treatment is a commonly used intervention to manage circadian rhythm sleep disorders, and several studies have supported its effectiveness for shift workers at night. In simulated night-work experiments, scheduled exposure to bright light has been shown to reduce night workers' complaints of sleepiness, reduced performance and disturbed sleep associated with the circadian rhythm (Bjorvatn et al., 1999; Sadeghniiat-Haghighi et al., 2011). Bright light treatment also facilitated workers' adaptation to night work and their re-adaptation to day life. Bjorvatn et al. (2007) evaluated the effects of bright light and melatonin on shift workers. Workers were either given melatonin 1 hour before bedtime, or exposed to bright light for 30 minutes, 2 hours before their habitual time of awakening (Bjorvatn et al., 2007). The findings suggest that bright light treatment and melatonin modestly improved re-adaption, sleep and sleepiness in swing shift workers.

Furthermore, preliminary industry findings by Roach et al. (2022) have proposed two types of interventions that may potentially be used to increase workers' adaptation. First, Roach et al. (2022) suggest that the delay signal (i.e., when an individual's body clock runs too slow and gets behind the day) provided by exposure to moderate-intensity light during rest breaks could be enhanced by several short exposures to high-intensity light (e.g., use LED glasses for 5 minutes each hour from 23:00 – 5:00h). Second, the advance signal (i.e., when an individual's body clock runs too fast and gets ahead of the day) provided by moderate/high-intensity light in the period between finishing work and going to bed in the morning could be reduced by light-shielding strategies (e.g., block-out blinds, wearing low-transmission blue-light blocking glasses).

The findings from these studies suggest that short-term bright light treatment of at least 30-minutes and the provision of melatonin 1 hour before bedtime may assist with the adaptation to night-work shifts by decreasing sleepiness and increasing work performance whilst supporting the subsequent re-adaptation to day life. Finally, re-adaptation may also be assisted with several short exposures to high-intensity light or light-shielding strategies.

### 2.1.2 Work Scheduling/Rostering

In terms of studies investigating the effects of work schedules on fatigue risk, various findings have been reported. Ganesan et al. (2022) assessed the alertness and performance of haul truck drivers on consecutive night shifts and identified that these two factors were impaired at the end of both night shifts. However, greater performance impairments were found at the end of the second night shift. Therefore, findings suggest that during consecutive days of the night shift, workers must be provided with adequate recovery sleep to remain alert and reduce the risk of fatigue-related injuries. In contrast with these findings, Leary and Cliff (2003) evaluated different shift cycles and rosters and found no relationship between shift cycle, rosters, and risks of work-related injury. However, it is of significance to note that this was a benchmark study and the data used to draw these conclusions were collected from a single mining company.

Upon further examination of schedule changes, such as switches to and from daylight saving, Barnes and Wagner (2009) found that time phase changes have adverse side effects on workers' safety. In Study 1, they found that, in comparison with other days of the week, on the Mondays directly following the switch to Daylight Saving-Time (DST) (i.e., 1 hour of potential sleep time lost), workers sustained more workplace injuries and injuries of greater severity. Study 2 extendeded these findings by providing indirect evidence for the mediating role of sleep: Specifically, workers were found to have slept on average 40-minutes less on the Monday following DST as compared to other days. Furthermore, when the workers switched to Standard Time (i.e., 1 hour of potential sleep time gained), analysis of the data revealed that there were no signficant differences in sleep, injury quantity or severity.

Donoghue et al. (2014) conducted a review of studies in the bauxite mining and alumina refining industries finding organisations had implemented interventions such as overtime limits, workforce planning to ensure adequate staffing levels, roster design, fatigue monitoring, and education, but did not report the efficacy of these interventions.

A review by MISHC (2005) placed a large emphasis on break times. Findings suggest that an extensive focus on fatigue management in the mining industry may have led to the absence of any clearly identifiable impacts of work break patterns. However, the Work Effectiveness Model by MISHC (2005) may be valuable in assessing the adequacy of work break patterns in mining.

*Extended workday scheduling*

Several academic and industry studies have investigated the prevalence of ‘standard’ or ‘regular’ shift lengths (8 hours) versus extended work schedules in the mining industry, finding a trend towards extended shifts (Heiler, 2001). Extended workday scheduling involves extending a worker’s regular shift length from 8 hours to a 10- or 12-hour schedule while maintaining an approximately 40-hour work week. In addressing possible adverse safety and work performance effects of such schedules, studies have compared workers' psychomotor and physiological performance and absenteeism in mining environments across different shift schedules (Baker et al., 2001; Duchon, 1992). In Duchon’s (1992) study, cognitive and psychomotor behavioural performances were measured pre-, mid- and post-shift. Findings identified no changes in psychomotor or physiological performance between a regular 8-hour shift and a 12-hour shift schedule. Further, Duchon et al. (1997), who monitored the heart rate of workers during 8-hour and 12-hour shifts, also found that the extended workday schedule did not lead to pronounced fatigue effects. Analysis of the heart rate data suggested that the absence of an effect for fatigue may be due to the pacing of work effort on the 12-hour shifts compared to the 8-hour shifts.

However, more recent studies evaluating the long-term effects of extended workday scheduling indicate that 12-hour shifts may lead to increased adverse health outcomes (Asare et al., 2021) and fatigue-related risk from chronically restricted sleep (Paech et al., 2010). A study by Paech et al. (2010), assessed the impact of four differing rostering schedules on workers’ sleep and sleep quality. Findings suggest that restricted sleep and quick shift-change periods may lead to long-term sleep loss and associated fatigue. Friedman et al. (2019) also found that, after the adoption of the 10- to 12-hour shift, the number of injuries multiplied three-fold, with injuries mainly occurring 9 hours into the shift or later. An extended workday (12 hours) has also been shown to affect workers' sleep quality and insomnia during the day and night shifts (Waage et al., 2012). Last, while Baker et al. (2001) found no significant negative effects from a 12-hour pattern, once unregulated overtime was introduced without consultation, absenteeism rates increased.

Despite these inconsistent findings on the effects of extended workday shifts, Baulk et al. (2009) suggest that effective fatigue management in this context requires both employers and employees take responsibility. For employers, this means scheduling shifts to allow for adequate rest and recovery, educating workers around fatigue, and adequately assessing fatigue-related risks associated with work tasks and conditions. For employees, it means utilising their break times and non-workdays to ensure that they have sufficient rest, and reporting fatigue-related hazards. Employee consultation regarding roster changes may also be influential in improving absenteeism outcomes (Baker et al., 2001). Nonetheless, a more stringent data collection method may be required to record other factors (e.g., overtime hours of work) to inform future risk management strategies (Cliff, 2005).

*Interventions altering shift start- and end-times*

Several studies have also explored interventions altering the start- and end-times of shifts. Rosa et al. (1996) conducted a study to evaluate a work schedule designed to improve sleep and alertness in day shift workers by delaying start- and end-times (i.e., one hour delay in shift starting time). The study findings indicate improved psychophysical factors such as decreased sleepiness and increased alertness with later start-times. In support of later start-times to improve sleep quality and quantity for day shift workers, this strategy also helps improve desynchrony (i.e., misaligned biorhythms where sleep/wake patterns do not coincide with external cues from light exposure within a regular twenty-four hour cycle) on days off and during shift transitions (Zhou et al., 2022). However, delaying start- and end-times also imposes a trade-off for night shift workers (by increasing their fatigue and sleepiness), and may cause dissatisfaction among day shift workers due to social impacts (by reducing the time available to spend with friends and family in the evenings) (Rosa et al., 1996).

*Work scheduling and rostering summary*

Overall, the prevalence of fatigue management interventions for work scheduling and rostering within the mining industry is relatively well researched. However, the use of extended workdays has yielded many conflicting findings for fatigue outcomes. Allowing for earlier start- and end-times has been shown to be ineffective for night shift workers, as they reported greater sleepiness and reduced alertness, while dayshift workers experienced reduced sleepiness and fatigue but an incompatibility with social aspects of life. Many studies evaluated  approaches to identify the most optimised scheduling for the industry. First, findings suggest that an ideal shift system should holistically consider and balance factors such as operational requirements, health and safety outcomes, and family and social life (Langdon et al., 2016; Pelders et al., 2021). Similarly, worker-driven scheduling processes that include operational requirements, employee preferences and optimised physiological factors were also found to be in line with positive health and safety outcomes such as fewer sleep disturbances and a better work-life balance (Castellucci & Altamirano, 2018; Davis & Aguirre; Peetz & Murray, 2011).

### 2.1.3 Psychosocial Hazards

Psychosocial hazards are a common contributing factor to work-related stress and fatigue. Primary work-related risk factors, including high role overload, increased responsibility, enhanced physical environmental stressors and reduced coping resources, are positively associated with workers' sleep disturbances (Jiang et al., 2021). Further findings suggest that workers' experiencing these work stressors and a decrease in coping resources will show an increased risk of sleep disturbances and impact on overall worker fatigue. These findings highlight the potential value of interventions to manage psychosocial hazards in order to minimise workers' sleep disturbances.

### 2.1.4 Environmental Conditions

The work environment, especially in the mining industry, can be a contributing factor to worker fatigue and psychophysical risks. Relevant environmental factors in the mining industry include high humidity, temperature and dust levels, poor air quality, and machinery noise and vibration (Marcin et al., 2020). From a holistic perspective of addressing worker fatigue, Butlewiski et al. (2015) proposed a miner fatigue system strategy to address safety and reduce the number of work accidents and errors to improve the health and well-being of workers. An essential part of the Butlewski et al. (2015) fatigue-oriented safety system was the need to identify environmental factors contributing to miner fatigue such as microclimate, noise, vibration, air composition, lighting, the impact of limited natural light, radiation and dust. The Butlewski et al. (2015) system was only proposed as a draft and did not include elements of a traditional fatigue risk management system such as lack of sleep, time of day or time on task, and no formal evaluation of its efficacy was reported. Nonetheless, Butlewski et al.'s (2015) emphasis on the impact of environmental conditions as a factor in fatigue may be important and is sometimes overlooked in current mining industry guidance (as seen in Section 2.2 below).

*Heat Exposure*

Intervention or evaluation studies assessing control measures for fatigue associated with working in hot and humid environments suggest that it is important for workers to be provided with education on the importance of hydration and self-pacing (i.e., slowing the work rate or resting more often in worse or high-temperature conditions), as well as early symptom reporting of heat exhaustion (Donoghue et al., 2000). In terms of the effectiveness of self-pacing, it is important to consider that this strategy was only found to be effective in reducing the risk of heat exhaustion within certain environmental conditions (i.e., 30 degrees and under) (Brake and Bates, 2001).

### 2.1.5 Commuting

A challenge that the mining industry faces is how to best manage the effects of worker fatigue during their commute to and from work. Shift workers often commute long distances to and from their work site. Findings reveal that workers usually commute with little or no rest following their work shift, which increases the risk of driving accidents attributed to fatigue-related risks such as inadequate rest or sleep (Rogers & Whitwell, 2009). However, these findings also indicate that implementing voluntary rest breaks for commuting mineworkers before driving is not an effective form of fatigue management strategy by itself (Rogers & Whitewell, 2009). A review by Zhang and Kecojevic (2014) recommended both traditional (e.g., safety regulations, training, engineering of work environment) and innovative (e.g., truck safety technologies) techniques to help mitigate driver fatigue and reduce the risk of fatigue-related accidents. A series of studies assessing the causes and incidence of driver fatigue in the Australian coal mining industry have also recommended two broad strategies to address the risk of driver fatigue: that the industry should consider implementing an education campaign and, second, review the effectiveness of offering a sleep facility for drivers (Di Milia & Smith, 2004), although these recommended interventions were not evaluated as part of their work.

### 2.1.6 Fatigue Identification or Assessment Methods

Studies have evaluated various fatigue identification or assessment methods as a first step in better targeting control measures for fatigue risk in the mining industry. First, to assess the impact of rotational shift work on the risk of accident and injury, d'Ettorre et al. (2020) developed and evaluated a modified version of the Rotational Shift work Questionnaire (RSQ-I), which assesses sentinel events (i.e., unexpected occurrences involving serious physical or psychological injury) and the presence of a range of risk factors in relation to rotational shift worker health and safety. The RSQ-I was reported to be an effective tool for assessing risks associated with rotational shift work. Application of the tool revealed a moderate level of risk in the particular minerals industry organisation that was investigated. The researchers suggested that interventions should focus on managing and minimising the impact of rotational shift work risks on workers' safety and health.

*Bio-mathematical models and fatigue detection technologies*

To support the importance of providing shift workers with adequate sleep, Wilson (2013) evaluated the use of a bio-mathematical model to design and validate shift work rosters. This is done by ensuring that workers have the opportunity to obtain adequate sleep and that the actual sleep workers obtain is quantified and verified against the shift roster model. The authors proposed that this model can be utilised as a tool to design holistic fatigue management systems to determine individual sleep/wake patterns and improve workers' sleep hygiene, reduce the risk of fatigue-related accidents, and increase performance effectiveness.

Studies have also developed mathematical models to identify the level of fatigue risk in the mining industry. First, a prominent bio-mathematical model of fatigue, the Fatigue

Assessment Tool by InterDynamics (FAID) has been a commonly used  to identify fatigue risk. For example, a study by Fletcher (2010) looked to identify safety in remote sites and used the FAID bio-mathematical model to predict the impact of hours worked on worker fatigue. The FAID has also been used to identify fatigue risk in haul truck drivers (Worrall, 2005). A study by Adyatama et al. (2019) also evaluated a logistic regression statistical method using various factors (e.g., workload, sleep duration) as an indicator of worker fatigue to determine an accurate measure of driver fatigue during hauling activities. Other reviews have also looked to the possibility of detecting driver fatigue levels through electroencephalography (EEG; Zhao et al., 2021); an alertness monitoring system (e.g., infra-red oculography-based Optalert Alertness Monitoring System (OAMS); Aidman et al., 2015); or non-intrusive machine vision technologies; Sun et al., 2015). A fuzzy neural network-based fatigue detection method was also proposed by Sun (2017) to determine driver fatigue levels by measuring various driver behaviours, such as head nods and yawn frequency.

Technologies that detect operator fatigue and alertness levels have progressed substantially in the past 20 years. Previously, Horberry, Hartley, Mabbott and Krueger (2001) stated that such technologies should never be the sole part of a company fatigue management system. Nowadays, fatigue detection technologies can form a key component of a mining fatigue management system; leading systems currently deployed include the SmartCap, the Operator Alertness System by Guardvant and the Driver Safety System by Caterpillar/Seeing Machines (Pollard, 2022 personal communication). As an example, a fatigue detection technology was piloted by Bongers (2009): this technology was the SmartCap system, a wearable cap with sensors capable of measuring the EEG of the individual. Findings suggest that this fatigue detection technology can reduce the occurrence of fatigue-related safety incidents on- and off-site, although operator acceptance of such a potentially intrusive device could be an issue. Further discussion of fatigue detection technologies is given throughout this report, especially regarding Glencore’s beneficial use of the Operator Alertness System in coal mines in NSW and Queensland (it should be noted that although Glencore coal mines NSW and Queensland use the Operator Alertness System, in Queensland Glencore’s mines do not use the associated Health TARP and Fitness for Work Assessments due to the requirements of the CMSH Regulation).

### 2.1.7 Training

Education or training are frequent fatigue countermeasure strategies evident in the literature; however, the effectiveness of these training programmes is rarely evaluated. For example, a preliminary study by Maisey et al. (2020) aimed to evaluate the efficacy of a sleep education program and biofeedback through a smartphone app reporting on sleep quality, quantity, and alertness; however, findings are yet to be concluded.

A review by Langdon et al. (2016) found evidence of risk to worker health in FIFO and DIDO populations from issues such as roster design, working hours, fatigue, safety performance, employee wellbeing, turnover, psychosocial relationships, and community concerns with sleep disruption and accumulated fatigue due to work hours. They reported gaps in the management risk to workers' health with regards to identifying roster designs and hours worked, as well as individual concerns such as feelings of isolation, physiological and general health affected the level of physical and mental risk of workers. Consequently, Langdon et al. (2016) suggest that implementing a health promotion framework within the industry may promote the health of these workers.

Several studies have focused on alertness and fatigue training for drivers in the mining industry, including drivers of heavy vehicles (Gander et al., 2005) and long-haul truck drivers (Pylkkönen et al., 2018). In Gander et al. (2005), a 2-hour fatigue management education intervention was conducted by a trained presenter. Participants' scores on a test about fatigue causes and countermeasures improved from pre- to post-training, suggesting at least a short-term increase in knowledge about fatigue management. Most drivers who chose to complete a follow-up survey 1-26 months later reported that they perceived the training to be at least moderately useful, and around half of them reported that they had changed the fatigue management strategies that they use. However, results from a driver alertness education intervention by Pylkkönen et al. (2018) show less promising findings. Participants in the study underwent a 3.5-hour alertness management training program; however, there was no significant improvement in driver sleepiness, suggesting that the training was insufficient to alleviate driver sleepiness. Despite several studies evaluating training of drivers in the mining industry, there are limited findings in relation to education or training in alertness or fatigue management.

### 2.1.8 Combined Interventions

Several studies focused on broader risk mitigation systems for fatigue. First, Mehta et al. (2019) indicated that effective fatigue management methods and techniques originate from both the organisation and the worker. Findings reveal factors that are in line with concurrent fatigue management interventions, such as the need to: improve sleep quality and quantity (Zhou et al., 2022); reduce excessive physical and cognitive workload (Jiang et al., 2021) through improving work, tools and environmental designs (Butlewski et al., 2015); and conduct periodic fatigue monitoring (Mehta et al., 2019). Implementing these fatigue management techniques may contribute to industry and production costs (Eiter et al., 2014), but long-term benefits also included reduced worker fatigue, psychosocial risks, and adverse safety outcomes, as well as improvements in work productivity, worker satisfaction, and workers' physical health (Maisey et al., 2022).

Second, several studies also looked at worker fatigue and its implications for health outcomes using risk assessments. For example, Muller et al. (2008) demonstrate that diurnal rhythm and night shifts of more than eight nights might be a primary contributing factor to occupational fatigue within the mining industry.

Leisure time activities have also been revealed to be beneficial for recovery from work-related fatigue, serving as a process that is important for the worker's health maintenance (Merkus et al., 2017). Ljoså and Lau (2009) examined the roles of workers' coping strategies and their locus of control for handling social and domestic life problems. Coping styles (i.e., Coping with Shiftwork Questionnaire) and shiftwork locus of control (i.e., Shiftwork Locus of Control Scale) were measured alongside shift arrangements and whether shift schedules affected workers' social and domestic lives. Findings suggest that coping strategies (e.g., social support) were beneficial in assisting workers to deal with shift-related problems (e.g., lack of time with family due to shiftwork). Last, a study by Ferguson et al. (2010) that focused on understanding the effects of leisure time on worker fatigue, found that increased leisure time may not necessarily reduce fatigue. Instead, work-related factors such as shift start times and day length were critical mediators of sleep quality and fatigue.

Finally, several studies have also focused on interventions to promote the well-being and mental health of workers in the mining industry. First, Perring et al. (2014) and Lovell and Critchley (2010) found a positive impact of efforts to increase social inclusion and community connectedness by implementing recreational and community infrastructure at mining camps. They found that, as a result of these interventions, workers can experience enhanced social interactions, improved well-being, and reduced social exclusion. Approaches surrounding personal support have also included the provision of 24/7 on-site chaplains, which led to enhanced mental health and reduced psychological distress in shift workers (Ebert & Strehlow, 2017). Moreover, the study found that the stigmatisation of mental health is also a predictor of psychological distress among shift workers in the mining industry. Therefore, findings suggest that integrating mental health education programs tailored to the industry may be important in reducing psychological distress in workers (Bowers et al., 2018).

## 2.2 Regulatory and other government information

In most states, workplace health and safety follows the Worksafe Australia Model Workplace Health and Safety (WHS) Acts and Regulations, with the most recent legislation coming into effect in 2022 and including directives on managing psychosocial risks. While the Acts and Regulations cover hazard risk management more generally, the recognised standards and codes of practice offer more breadth and depth in terms of risk management practices in each jurisdiction, where fatigue is more generally captured alongside other hazards[2]. Guidance notes, meanwhile, provide advice on how people conducting a business or undertaking can meet their obligations in the respective regulations, with specific guidance notes focused on fatigue risk management[3]. The mining industry usually is governed by specific mining regulation within the broader WHS regulatory scheme. In Queensland, the Coal Mining Safety and Health Act 1999 and the Mining and Quarrying Safety and Health Act 1999 are in force, with their associated regulations and standards or guidelines, and they encompass the safety obligations of Mine Operators and individuals. In terms of fatigue, while more generally captured in the Acts and Regulations mentioned, the Queensland Guidance Note (QGN16) provides advice on more holistic fatigue risk management practices.

The Coal Mining Health and Safety Regulation (2017) in Queensland has set out specific regulations regarding controlling risks at the mine associated with the following: (a) personal fatigue; (b) other physical or psychological impairment and; (c) the improper use of drugs. These controls include education programs, employee assistance programs, the maximum number of hours worked (in a day and in a week), and the number and length of rest breaks. This requirement is not specifically mentioned in other regulations such as the Work Health and Safety (Mines) Regulation (2022) in Western Australia and Work Health and Safety (Mines) Regulation (2014) in New South Wales In the Work Health and Safety (Mines) Regulation (2022) and Work Health and Safety (Mines) Regulation (2014), both state that the mine operator of a mine must manage risks to health and safety associated with worker fatigue. This includes conducting a risk assessment and ensuring that any risk

---

[2] A code of practice does not have the same legal force as a regulation and is not sufficient reason, of itself, for prosecution under the legislation, but it may be used by courts as the standard when assessing other methods or practices used.

[3] A guidance note is purely advisory and offer non-binding advice.

assessment conducted is done by a competent person having regard to the nature of the hazard. They must also have regard to the likelihood of the hazard affecting the health or safety of a person and the severity of the potential health and safety consequences. The requirements for a risk assessment under the Queensland regulations are covered under the general requirements for developing a Standard Operating Procedure (CMSHR, 2017, Chapter 2, section 10.3). However the Fitness for Duty provisions require agreement from a majority of the workforce which is more stringent than the requirements under section 10, for other SOP.

The transport industry broadly follows a Master Code of Practice, which consolidates the various fatigue management practices under the Heavy Vehicle National Law[4]. Here they cover fatigue-related items such as risk types (e.g. *workplace factors like job demands*) and suggested controls (e.g. *more frequent breaks from driving*). The National Transport Commission (NTC) also provides guidance notes on managing heavy vehicle driver fatigue.

The offshore industry follows the legislation set out under the Offshore Petroleum and Greenhouse Gas Storage Act 2006. The National Offshore Petroleum Safety and Environment Management Authority (NOPSEMA) provides guidance notes on fatigue avoidance, and covers items such as fatigue prevention barriers (e.g. *appropriate staffing*), fatigue proofing barriers (e.g. *task scheduling*), and system monitoring and improvement (e.g. *accident and dangerous occurrence investigation*).

The Aviation industry follows the Civil Aviation Act 1988, with fatigue management processes falling under the Civil Aviation Order 48.1 Instrument 2019. The instrument covers items such as fatigue management obligations (e.g. *identifying any reasonably foreseeable hazard that may compromise an flight crew member (FCM)'s alertness during a flight duty period (FDP)*).

[4] Western Australia has chosen not to follow the guidelines set out in the Heavy Vehicle National Law.

Looking internationally, there is no formal regulation of hours of work or requirement for fatigue management in the US mining industry. The Fair Labour Standards Act (https://www.dol.gov/agencies/whd/flsa) regulates hours of work for persons under the age of 16. Some industries such as aviation (Federal Aviation Administration, 14 Code of Federal Regulations (CFR) Part 117, 2009), Nuclear Power (Nuclear Regulatory Commission, 10 CFR Part 26) sub part I, 2022), and transport (Federal Motor Carrier Safety Administration (https://www.fmcsa.dot.gov/regulations/hours-of-service) , Federal Railroad Administration (49 CFR 270 and 271, 2022) do have specific regulations limiting the hours of work for some workers. The National Institute for Occupational Safety and Health has established the Center for Work and Fatigue Research which partners with other US Government Agencies to promote awareness of worker fatigue, identify effective methods to assess fatigue-risk in workplaces and to reduce health and safety risks associated with fatigue. The website https://www.cdc.gov/niosh/programs/ppops/cwfr.html provides a link to information resources. The website also references a publication by Wong and Swanson (2022) Approaches to managing work-related fatigue to meet the needs of American workers and employers that summarises a 2019 national forum hosted by NIOSH and includes a number of references to studies presented at this forum, including a publication by Bauerle et al (2021) on The Human Factors of mineworker fatigue: An Overview on prevalence, mitigation, and what's next. This paper has been included in the literature review in section 5. It promotes the need to explore further the origins, nature and outcomes of fatigue using advancements in lighting, automation and fatigue risk management. It notes that mining specific research to date has been limited.

To identify how fatigue is captured across the various legislative documents, a comparison was made on fatigue risk management practices across the Model WHS laws, as well as legislation in Queensland, Western Australia, and New South Wales [5] (see Table 1). Table 2 compares the various recognised standards / codes of practice in mining from Queensland, Western Australia, New South Wales, and from the general health and safety space, with regards to the mining industry. Additionally, after consultation with a subject

[5] Legislation that specifically cover fatigue management are expanded upon, with key obligations outlined. For extensive regulations, a summary of the obligation is outlined. Codes of Practices and Recognised Standards are compared in Table 2. Guidance Notes are compared in Table 3.

matter expert on mining fatigue (Dawson, 2022 personal communication)[6], the regulations by international government bodies were included in Table 3. Table 4 compares the guidance notes in mining from Queensland and New South Wales, the general health and safety guidance from SafeWork Australia, and the general health and safety guidance note on fatigue management in Queensland. This allows us to focus on the largest mining states in Australia, and align with the collated data from mining sites, which will be discussed in a later section.

Appendix A (separate Excel document) contains additional comparisons between the Codes and Guidelines. Appendix B (separate Excel document) contains a full description of the CMSH section 42 requirements.

Section 6.1 undertakes a wider gap analysis of Queensland legislation against best practice fatigue management elsewhere.

---

[6] The international fatigue management regulations and the general health and safety guidance on fatigue management in Queensland are considered best practice by Dawson (personal communication, 2022).

**Table 1**. How/Where fatigue is captured across Queensland, Western Australia, and New South Wales

| | Minerals | | | Transport | | | General Health & Safety | Offshore | Aviation |
|---|---|---|---|---|---|---|---|---|---|
| **State** | **QLD** | **WA** | **NSW** | **QLD** | | **NSW** | **National** | | |
| **Acts** | **Mining and Quarry Safety and Health Act 1999 / Coal Mining Safety and Health Act 1999**<br>Captured under Safety and Health Obligations, Part 3 | **Work Health and Safety Act 2020**<br>Captured under Division 2, Part 19, Primary duty of care | **Work Health and Safety (Mines and Petroleum Sites) Act 2013**<br>Captured in Work Health and Safety (Mines and Petroleum Sites) Regulations 2014 | **Transport Operations (Road Use Management) Act 1995**<br>Captured in Transport Operations (Road Use Management—Fatigue Management) Regulation 2008 | **Heavy Vehicle National Law (Queensland)**<br>Captured under Chapter 6, Vehicle Operations – Driver Fatigue; Part 6.2, Duties relating to fatigue; Division 2, Duty to avoid fatigue; 228<br><br>*A person must not drive a fatigue-regulated heavy vehicle on a road while impaired by fatigue.* | **Heavy Vehicle National Law (NSW) No 42a of 2013**<br>Captured under Chapter 6, Vehicle Operations – Driver Fatigue; Part 6.2, Duties relating to fatigue; Division 2, Duty to avoid fatigue; 228<br>*A person must not drive a fatigue-regulated heavy vehicle on a road while impaired by fatigue.* | **Model WHS Act 2022**<br>Captured under Division 2, Part 19, Primary duty of care | **Offshore Petroleum and Greenhouse Gas Storage Act 2006**<br>Capture in Offshore Petroleum and Greenhouse Gas Storage (Safety) Regulations 2009 | **Civil Aviation Act 1988**<br>Captured in Civil Aviation Order 48.1 Instrument 2019 |
| **Regulations** | **Coal Mining Health and Safety Regulation 2017**<br>Captured under Part 6, Fitness for Work; Division 1, General<br><br>42, Safety and health management for personal fatigue and other physical and psychological impairment, and drugs (see Appendix B)<br><br>*Mining and Quarrying Safety and Health Regulation 2017 Captured under Chapter 2 Parts 86 and 89*<br><br>**86 Worker's self-assessment of fitness level.** Each worker at the mine must periodically conduct a self-assessment of the worker's condition, including, for example, for effects of heat strain or fatigue, to decide if the worker is in a fit condition to carry out the worker's duties at the mine without creating an unacceptable level of risk.<br>**89 Work hours and rest breaks.** A mine's safety and health management system must provide for controlling risk at the mine arising out of personal fatigue caused by excessive work hours or insufficient rest periods. | **Work Health and Safety (Mines) Regulation 2022**<br>Captured under Chapter 10, Mines: Part 10.2, Managing Risks; Division 3, Specific Control Measures – All Mines; Subdivision 3, Fitness for Work; 640, Fatigue<br><br>*In complying with regulation 617, the mine operator of a mine must manage risks to health and safety associated with worker fatigue.* | **Work Health and Safety (Mines and Petroleum Sites) Regulations 2014**<br>Captured under Part 2, Managing Risks; Division 4, Specific Control Measures – All Mines and Petroleum Sites; Subdivision 3, Fitness for Work; 43, Fatigue<br><br>*In complying with clause 9, the operator of a mine or petroleum site must manage risks to health and safety associated with worker fatigue.* | **Transport Operations (Road Use Management—Fatigue Management) Regulation 2008**<br>Captured under Part 2, Duties relating to fatigue; Division 3, Duty to avoid and prevent fatigue<br><br>*All parties in the chain of responsibility (including the driver) must take all reasonable steps to ensure a person does not drive a fatigue-regulated heavy vehicle while impaired by fatigue.* | **Heavy Vehicle (Fatigue Management) National Regulation 2018**<br>Captured in Heavy Vehicle National Law (Queensland) | **Heavy Vehicle (Fatigue Management) National Regulation (NSW) (2013 SI 245a)**<br>Captured in Heavy Vehicle National Law (NSW) No 42a of 2013 | **Model WHS Regulations 2022**<br>Captured under Division 11, Psychosocial Risks; 55C Managing Psychosocial Risks<br><br>*A person conducting a business or undertaking must manage psychosocial risks in accordance with Part 3.1 other than regulation 36.* | **Offshore Petroleum and Greenhouse Gas Storage (Safety) Regulations 2009**<br>Captured under Chapter 3, Occupational Health and Safety; Part 1, Health and Safety; Section 3.1, Avoiding Fatigue<br><br>*The person must not allow, or require, a member of the workforce who is under the person's control, to work for a duration that could reasonably be expected to have an adverse effect on the health or safety of the member of the workforce or other persons at or near the facility.* | **Civil Aviation Regulations 1988 / Civil Aviation Safety Regulations 1998**<br>Captured in Civil Aviation Order 48.1 Instrument 2019 |
| **Recognised Standards / Code of Practice** | | **Working Hours Code of Practice** | **Safety Management Systems in Mines: NSW Code of Practice** | | **Master Code<br>A registered industry code of practice under section<br>706 of the Heavy Vehicle National Law** | | **Managing Psychosocial Hazards at Work: Code of Practice 2022**<br><br>**How to Manage Work Health and Safety Risks: Code of Practice 2018** | | |
| **Guidance Notes** | **Queensland Guidance Note 16 (QGN16)** | | **Fatigue Management Guidance for the NSW mining, petroleum and extractive industries** | **National Transport Commission (NTC)<br>Guidelines for Managing Heavy Vehicle Driver Fatigue** | | | **Guide for managing the risk of fatigue at work** | **NOPSEMA Avoiding Fatigue Guidance Note** | |

**Table 2**. Comparison of Codes of Practice in Mining and General Health and Safety

| | Minerals | | General H&S | |
|---|---|---|---|---|
| | WA | NSW | National | |
| **Risk Management Processes** | **Working Hours Code of Practice** | **Safety Management Systems in Mines: NSW Code of Practice** | **Managing Psychosocial Hazards at Work: Code of Practice 2022** | **How to Manage Work Health and Safety Risks: Code of Practice 2018** |
| **Obligations to Manage Fatigue** | **Employers, Employees**<br>*"The employer's general 'duty of care' obligations for safety and health under the OSH Act and the MSI Act include:*<br>*• providing a workplace and safe system of work so employees are not exposed to hazards."*<br><br>*"Employees also have obligations under the OSH Act and the MSI Act. They must take reasonable care to ensure their own safety and health at work and that of others affected by their work and report any situations that may be hazardous."* | **PCBUs**<br>*"The WHS Act requires all persons conducting a business or undertaking (PCBU), including the mine holder and the mine operator, to ensure, so far as is reasonably practicable, the health and safety of workers and that the health and safety of other people is not put at risk from work carried out as part of the business or undertaking. This means eliminating or minimising risks to health and safety, so far as is reasonably practicable."* | **PCBUs, Workers**<br>*"A PCBU must ensure, so far as is reasonably practicable, workers and other persons are not exposed to risks to their psychological or physical health and safety. A PCBU must eliminate psychosocial risks in the workplace, or if that is not reasonably practicable, minimise these risks so far as is reasonably practicable."*<br><br>*"Workers must take reasonable care for their own psychological and physical health and safety and to not adversely affect the health and safety of other persons. Workers must comply with reasonable health and safety instructions, as far as they are reasonably able, and cooperate with reasonable health and safety policies or procedures that have been notified to workers."* | **PCBUs, Workers**<br>*"A PCBU must eliminate risks in the workplace, or if that is not reasonably practicable, minimise the risks so far as is reasonably practicable."*<br><br>*"Workers have a duty to take reasonable care for their own health and safety and to not adversely affect the health and safety of other persons. Workers must comply with reasonable instructions, as far as they are reasonably able, and cooperate with reasonable health and safety policies or procedures that have been notified to workers."* |
| **Hazard Identification** | **Required**<br>*As part of the three-step risk management process as required under The Occupational Safety and Health Regulations 1996 (the OSH Regulations)* | **Required**<br>*As part of the four-step risk management process as required under the WHS (Mines) Regulation* | **Required**<br>*As part of the four-step risk management process as required under the code of practice* | **Required**<br>*As part of the four-step risk management process as required under the code of practice* |
| **Risk Assessment** | **Required**<br>*As part of the three-step risk management process as required under The Occupational Safety and Health Regulations 1996 (the OSH Regulations)* | **Required**<br>*As part of the four-step risk management process as required under the WHS (Mines) Regulation* | **Required**<br>*As part of the four-step risk management process as required under the code of practice* | **Required**<br>*As part of the four-step risk management process as required under the code of practice* |
| **Risk Control** | **Required**<br>*As part of the three-step risk management process as required under The Occupational Safety and Health Regulations 1996 (the OSH Regulations)* | **Required**<br>*As part of the four-step risk management process as required under the WHS (Mines) Regulation* | **Required**<br>*As part of the four-step risk management process as required under the code of practice* | **Required**<br>*As part of the four-step risk management process as required under the code of practice* |

| | | | | |
|---|---|---|---|---|
| **Reviewing Controls** | **Advised**<br>*"Constantly monitor and review the working hours control measures to ensure they continue to prevent or control exposure to hazards or hazardous work practices."* | **Required**<br>*As part of the four-step risk management process as required under the WHS (Mines) Regulation* | **Required**<br>*As part of the four-step risk management process as required under the code of practice* | **Required**<br>*As part of the four-step risk management process as required under the code of practice* |
| **Information, Instruction, Training and Supervision** | **Required**<br>*"The employer's general 'duty of care' obligations for safety and health under the OSH Act and the MSI Act include providing employees with information, instruction, training and supervision to enable them to work in a safe manner."* | **Required**<br>*"The mine operator has a duty to ensure a range of information, training and instruction is provided to workers, as required under the WHS (Mines) Regulation. Supervision is essential to check that work instructions and procedures are followed, and tasks are completed as required. What is appropriate to the mine and the number of supervisors required will depend on factors such as remote work and level of risk as required under the WHS (Mines) Regulation."* | **Required**<br>*"As you are planning to implement control measures, you must consider what information, training, instruction or supervision is required to ensure the control measures are effective."* | **Required**<br>*"Training, instruction and information must be provided in a form that can be understood by all workers... The level of supervision required will depend on the level of risk and the experience of the workers involved. High levels of supervision are necessary where inexperienced workers are expected to follow new procedures or carry out difficult and critical tasks."* |
| **Documentation** | **Not Mentioned** | **Required**<br>*"The mine operator must develop procedures for the management of all the records needed to comply with the WHS Act and WHS Regulations."* | **Advised**<br>*"You should record your risk management process and the outcomes, including your consultation with workers. This allows you to demonstrate you have met your work health and safety duties and will assist you when you need to monitor or review the hazards you have identified and controls you have put in place."* | **Advised**<br>*"Keeping records of the risk management process demonstrates what you have done to comply with the WHS Act and WHS Regulations. It also helps when undertaking subsequent risk management activities, including reviewing your control measures."* |

**Table 3**. Comparison of Regulations from International Government Bodies

| Risk Management Processes | American Federal Rail: Fatigue Risk Management Programs for Certain Passenger and Freight Railroads | Transport Canada: Duty and Rest Periods for Railway Operating Employees |
|---|---|---|
| **Obligations to Manage Fatigue** | **Required**<br>*"Railroads have a statutory obligation to create and implement Fatigue Risk Management Programs (FMRPs)"* | **Required**<br>*"Railroad companies are responsible for… managing employees in a manner that provides them with adequate sleep opportunity in order to return to work fit for duty… developing and implementing a fatigue management plan consistent with fatigue science and the requirements of this Rule"* |
| **Hazard Identification** | **Required**<br>*As part of the purpose and scope of a FMRP*<br>*E.g., "A railroad shall… develop its FRMP by systematically identifying and evaluating the fatigue-related railroad safety hazards on its system…"* | **Not Mentioned** |
| **Risk Assessment** | **Required**<br>*As part of the requirements for an FMRP*<br>*E.g., "A railroad shall include an analysis of fatigue risks…"* | **Risk Assessment Captured throughout the Elements in Support of the Duty and Rest Periods Rules as outlined in the Regulation**<br>*E.g., "The FMP shall include or reference a process to… report by employees that they are fatigued in a manner that may affect safe railway operations during a duty period that takes into account attendance management."* |
| **Risk Control** | **Required**<br>*As part of the requirements for an FMRP*<br>*E.g., "A railroad shall develop and implement mitigation strategies to reduce the risk of railroad accidents, incidents, injuries, and fatalities where fatigue of any of its safety-related employees is a contributing factor."* | **Risk Control Captured throughout the Elements in Support of the Duty and Rest Periods Rules as outlined in the Regulation**<br>*E.g., "The FMP shall include or reference a process to… ensure a minimum of 8 hours of the employees assigned rest period will be undisturbed by the company…"* |
| **Reviewing Controls** | **Required**<br>*As part of the requirements for an FMRP*<br>*E.g., "A railroad shall develop and implement procedures and processes for monitoring and evaluating its FRMP to assess whether the FRMP effectively meets the goals its FRMP plan describes…"* | **Required**<br>*As part of the Core Elements of a Fatigue Management Plan (FMP) as outlined in the Regulation*<br>*E.g., "A railway company shall develop and implement a FMP that includes or references… a process to monitor, evaluate and address the effectiveness of the FMP…"* |
| **Information, Training, Instruction, and Supervision** | **Advised**<br>*"A railroad shall consider developing and implementing training, education, and outreach methods to deliver* | **Required**<br>*As part of the Elements in Support of the Duty and Rest Periods Rules as outlined in the Regulation* |

| | | |
|---|---|---|
| | *fatigue-related information effectively to its safety related railroad employees."* | *E.g., The FMP shall include or reference a process to… train employees on these Rules and on fatigue in the rail industry…"* |
| **Documentation** | **Not Mentioned** | **Not Mentioned** |

**Table 4.** Comparison of Guidance Notes in Mining and General Health and Safety

| | Minerals | | General H&S | |
|---|---|---|---|---|
| **Fatigue Risk Management Processes** | **Queensland Guidance Note (QGN) 16** | **Fatigue Management Guidance for the NSW mining, petroleum, and extractive industries** | **Workplace Health and Safety Queensland: Preventing and managing fatigue-related risk in the workplace** | **Guide for managing the risk of fatigue at work (SafeWork Australia)** |
| **Recognition of Fatigue as a hazard** | **Yes** *"There is a direct link between fatigue and increased risk of being involved in an incident or accident."* | **Yes** *"Unmanaged fatigue related impairment is both an organisational and individual hazard."* | **Yes** *"Fatigue is a state of mental or physical exhaustion which reduces a person's ability to perform work safely and effectively."* | **Yes** *"Fatigue can adversely affect safety at the workplace. Fatigue reduces alertness which may lead to errors and an increase in incidents and injuries."* |
| **Organisational Obligations to manage fatigue** | **Yes** *"Operators and SSEs hold the fundamental obligation for managing the risks associated with fatigue."* | **Yes** *"The PCBU (s19 WHS Act 2011) has the primary duty to ensure the health and safety of workers."* | **Yes** *"A PCBU has the primary duty to ensure, so far as is reasonably practicable, workers and other people are not exposed to health and safety risks arising from the conduct of the business or undertaking".* | **Yes** *"The PCBU has the primary duty to ensure, so far as is reasonably practicable, workers and other persons are not exposed to health and safety risks arising from the business or undertaking."* |
| **Individual Obligations to manage fatigue** | **Yes** *"All workers on-site, including contractors and other on-site service providers, must be involved in implementing the fatigue risk management plan and in making sure it is followed."* | **Yes** *"Workers (including contractors, apprentices, students, labour hire workers, volunteers) have a duty to ensure fatigue does not create a health and safety risk at work."* | **Yes** *"A worker must take reasonable care of their own health and safety in the workplace, and the health and safety of others who may be affected by their actions."* | **Yes** *"Workers must take reasonable care for their own health and safety and must not adversely affect the health and safety of other persons."* |
| **Worker Consultation** | **Yes** *"Consultation must be undertaken as required by legislation."* | **Yes** *"Operators and other PCBUs must consult with workers when developing and implementing strategies to manage fatigue."* | **Yes** *"PCBU's must consult, so far as is reasonably practicable, with workers and Health and Safety Representatives (HSRs), when, for example, identifying or assessing hazards or risks to health and safety at a workplace."* | **Yes** *"A person conducting a business or undertaking must consult, co-operate and coordinate activities with all other persons who have a work health or safety duty in relation to the same matter, so far as is reasonably practicable."* |
| **Roles and Responsibilities** | **Advised** *"The roles and responsibilities of persons within the organisation who will have responsibility for developing and implementing the plan should be identified."* | **Advised** *"Roles and responsibilities - fatigue management arrangements should set out the shared responsibilities of the organisation and workers with respect to managing fatigue. Specific fatigue risk management responsibilities should be outlined for managers, supervisors and workers, including contractors."* | **Roles and Responsibilities Captured Throughout the Document** *E.g., The Shared Responsibility Framework outlines specific responsibilities for workers (including contractors), and for the organisation i.e. the Person Conducting a Business or Undertaking (PCBU)."* | **Advised** *"A fatigue policy is not mandatory but may be an effective way to communicate the organisation's procedures to workers. Consider including information about: • roles and responsibilities of supervisors and workers"* |

| | | | | |
|---|---|---|---|---|
| **Resources** | **Required** *"Those responsible for the development and implementation of the fatigue risk management plan must ensure that appropriate resources are made available as per their legislative requirements under Queensland legislation."* | **Required** *"Operators and other PCBUs responsible for managing fatigue risks must ensure that appropriate resources are made available."* | **Required** *"Officers of the PCBU must… ensure the availability of appropriate resources and processes to identify and manage fatigue-related risks"* | **Required** *"Taking reasonable steps to ensure the business or undertaking has and uses appropriate resources and processes to manage the risks associated with fatigue."* |
| **Hazard Identification** | **Required** *As part of the four-step risk management process as required under the CMSH regulation* | **Required** *As part of the four-step risk management process as required under the WHS (MPS) regulation* | **Required** *As part of the four-step risk management process outlined in the guide* | **Required** *As part of the four-step risk management process outlined in the guide* |
| **Risk Assessment** | **Required** *As part of the four-step risk management process as required under the CMSH regulation* | **Required** *As part of the four-step risk management process as required under the WHS (MPS) regulation* | **Required** *As part of the four-step risk management process outlined in the guide* | **Required** *As part of the four-step risk management process outlined in the guide* |
| **Risk Control** | **Required** *As part of the four-step risk management process as required under the CMSH regulation* | **Required** *As part of the four-step risk management process as required under the WHS (MPS) regulation* | **Required** *As part of the four-step risk management process outlined in the guide* | **Required** *As part of the four-step risk management process outlined in the guide* |
| **Hierarchy of Controls** | **Yes** *Elimination, Substitution, Isolation, Engineering controls, Administrative controls, PPE* | **Yes** *Elimination, Substitution, Isolation, Engineering controls* | **Yes** *Elimination, Minimisation* | **Yes** *Elimination, Minimisation* |
| **Information, Instruction, Training and Supervision** | **Required** *"All site personnel, including contractors, must be informed about the fatigue risk management plan and have the skills and knowledge they need to fulfil their roles and responsibilities. Coal mine sites have obligations for an education program under the CMSH Regulation, s.42 (2). Legislation requires proper supervision of workers (including contractors) and appropriate supervision is an essential part of the fatigue risk management plan."* | ***Advised*** *"Information and training - fatigue management arrangements should identify skills and knowledge workers require in meeting their fatigue risk management responsibilities. Supervision - ensure workers and supervisors are competent to identify, report and manage fatigue risks. Fatigue management arrangements should identify skills and training required by workers to carry out their roles and responsibilities under the fatigue management arrangements."* | **Required** *"The PCBU must ensure, so far as is reasonably practicable, the provision of any information, training, instruction or supervision that is necessary to protect all persons from risks to their health and safety arising from work carried out."* | **Required** *"A person conducting business or undertaking must provide, so far as is reasonably practicable, any information, training, instruction or supervision necessary to protect all persons from risk to their health and safety arising from work carried out as part of business or undertaking."* |
| **Evaluation of Controls** | **Required** *As part of the four-step risk management process as required under the CMSH regulation* | **Required** *As part of the four-step risk management process as required under the WHS (MPS) regulation* | **Required** *As part of the four-step risk management process outlined in the guide* | **Required** *As part of the four-step risk management process outlined in the guide* |

## 2.3 Identification of controls in industry fatigue management documentation

This section of the report reviews industry information concerning their management of fatigue. Specifically, the process organisations employed to identify and implement procedural (soft) and practical (hard) controls to manage the risk of fatigue. In order to undertake this review, industry fatigue management procedures were required. Coal and mineral mining organisations were contacted by team members. The team requested access to any documentation mining organisations had developed to support their fatigue management processes. Contacts were informed that the documentation would be kept strictly confidential, and any publications would require their consent prior to release. Overall, seven mines/organisations provided fatigue management documentation. Each of these seven has been treated separately.

The controls identified in each of the documents volunteered by the seven mines/organisations were sorted into five broad categories that might represent threat lines on a bow-tie:

- work scheduling, planning and travel,
- work environment conditions,
- mental and physical work demands during shift,
- individual and non-work factors, and
- failure to identify fatigue.

The categories were taken from the fatigue bow-tie in the industry-based risk management tool, Riskgate (Kirsch, 2012).[7] A review of the fatigue guidance documents developed for the extractive industries in Queensland and New South Wales, plus that of the National Health and Safety Guide for Managing the Risk of Fatigue at Work, showed that all generally grouped fatigue risks (and controls) in a way similar to that used here, see Table 5. An exception was that the Riskgate taxonomy included ‘failure to identify fatigue’, which none of the other documents

[7] A number of the authors from the current project had been involved in the development of Riskgate’s fatigue bow-tie.

used. We found it useful as it primarily focused on mitigating controls, whereas the other four categories focused on preventative controls. This allowed us to capture companies' mitigating controls more suitably and more clearly differentiate them from their preventative controls. For example, all but one of the companies identified the role of the supervisor in identifying a fatigued worker, which is a mitigating control, and was grouped into the 'failure to identify' category.

As shown in Table 5, two of the other documents included a category concerning sleep, and another about the contribution of chronic fatigue, which we did not include as we believed controls around sleep and chronic fatigue were captured in our 'Work scheduling, planning and travel' and 'Individual and non-work factors' categories. Another difference was that the two extractive industry documents separated work scheduling from commuting. We preferred to collapse them as we believed the controls to manage them were common and inter-related to one another.

**Table 5.** Comparison of groupings used to sort fatigue risks and controls in Riskgate, QLD and NSW extractive industries' fatigue guidance documents and Safework Australia's fatigue guidance document

| Current groupings | QGN 16[8] | Fatigue Management Guidance for the NSW Mining, Petroleum, and Extractive Industries[9] | H&S Guide for Managing the Risk of Fatigue at Work[10] |
|---|---|---|---|
| | "Factors that contribute to fatigue" | | |
| 1.Work scheduling, planning & travel | 1.Work scheduling & planning | 1.Work scheduling & planning | 1.Work schedules – shift work, night work, hours of work, breaks |
| | 2.Long or excessive commuting times | 2.Commuting | |

[8] QGN16: Section 5.2

[9] https://www.resourcesregulator.nsw.gov.au/sites/default/files/documents/fatigue-management-guide.pdf (see section 4)

[10] https://www.safeworkaustralia.gov.au/system/files/documents/1702/managing-the-risk-of-fatigue.pdf (see section 2.1)

| | | | |
|---|---|---|---|
| 2.Work environment conditions | 3.Work environment conditions, & mental & physical demands of work | 5.Work environment conditions | 4. Environmental conditions |
| 3.Mental & physical work demands during shift | | 4.Demands of work | 2.Job demands |
| 4.Individual & non-work factors | 5.Individual & non-work factors | 3.Individual and non-work factors | 5. Non-work related factors |
| 5.Failure to identify fatigue | - | - | - |
| (Captured in groupings 1 & 4 above) | 4.Lack of restorative sleep | 6.Effect of exposure for longer periods | 3.Sleep – length of sleep time, quality of sleep and time since sleep |

**Note.** The last row of table 5 shows factors from the three external documents that were different to our groupings, but were merged into our first category (Work scheduling, planning & travel) or fourth category (Individual & non-work work factors).

Please see Appendix C for details, and Appendix D for full (de-identified) data. Table 6 below provides a summary of the risk controls each of the organisations reported in place against the five Riskgate categories. Please note when interpreting the following information, the review was conducted only on those documents that organisations provided. It is clear from reading these documents that other supporting documentation and processes existed in these organisations, but this information could not be obtained for the review. Therefore, the nature and types of controls organisations have in place on site may be different and/or broader.

At this high level it becomes clear that the predominate type of controls organisations have developed and implemented to manage fatigue in the workplace are procedural or soft controls. The pattern of having a larger number of procedural controls over practical controls is consistent across all organisations that volunteered their fatigue management documentation. However, as discussed in section 3.6, few fatigue incidents result in lost time injuries, potentially due to the mines better control of their environment in which heavy vehicles operate (e.g. road design).

**Table 6.** High level summary of the number of organisational controls against the Riskgate categories

| | Company 1<br><br>UG - Coal<br>DIDO - Village | | Company 2<br><br>OC - Coal<br>DIDO - Village | | Company 3<br><br>OC - Coal<br>DIDO - Village | | Company 4<br><br>OC - Coal<br>DIDO - Village | | Company 5<br>Corporate documents | | Company 6<br><br>UG - Coal<br>DIDO? | | Company 7<br><br>UG - Coal<br>DIDO - village | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Procedural (Soft) Controls | Practical (Hard) Controls | Procedural (Soft) Controls | Practical (Hard) Controls | Procedural (Soft) Controls | Practical (Hard) Controls | Procedural (Soft) Controls | Practical (Hard) Controls | Procedural (Soft) Controls | Practical (Hard) Controls | Procedural (Soft) Controls | Practical (Hard) Controls | Procedural (Soft) Controls | Practical (Hard) Controls |
| Work scheduling, planning and travel | 14 | 2 | 19 | 1 | 32 | 4 | 18 | 5 | 27 | 1 | 8 | 0 | 13 | 0 |
| Work environment conditions | 1 | 1 | 0 | 1 | 6 | 1 | 5 | 1 | 3 | 2 | 0 | 1 | 0 | 2 |
| Mental and physical work demands during shift | 2 | 0 | 0 | 0 | 1 | 0 | 1 | 2 | 3 | 5 | 0 | 1 | 0 | 1 |
| Individual and non-work factors | 1 | 0 | 1 | 0 | 6 | 0 | 8 | 0 | 8 | 0 | 2 | 1 | 2 | 0 |
| Failure to identify fatigue | 5 | 1 | 4 | 5 | 21 | 3 | 12 | 0 | 11 | 5 | 0 | 0 | 4 | 1 |
| Total*: pre-request | 23 | 4 | 24 | 7 | 66 | 8 | 44 | 8 | 52 | 13 | 10 | 3 | 19 | 4 |
| Total**: post-request | 23 | 5 | 24 | 7 | 66 | 8 | 50 | 13 | 52 | 13 | 10 | 3 | 19 | 4 |

* Total controls listed in original document submitted by companies

** Total controls listed in response to request for additional information. All original documents listed additional fatigue management material internal to the organisation. A request was made for this information. Company 4 responded to the request.

Table 7 provides detailed information for each of the Riskgate categories across each organisation. Several patterns emerge: ‘Work scheduling, planning and travel’ appears to be the category that most organisations have recognised as important for managing fatigue. This category includes a large range of controls including ‘roster design’ (e.g., Limitations on maximum shift hours (12.5) and limitations on number of consecutive shifts (7 day or night shifts); A minimum break of 10 hours will occur between shifts; etc), ‘implement fatigue management’ (e.g., Exceedances to the maximum shift hours are reported to the Supervisor who will manage the risk and record the event in EMS) and supervision and interaction during shift (e.g. Supervisors to conduct safety interactions for tasks identified as a high fatigue risk). This category appeared to identify the largest number of preventative controls. ‘Roster design’ and ‘Implement fatigue management plan’ were the most frequently implemented preventative controls, and predominantly featured procedural controls.

‘Failure to identify fatigue’ was also a category that featured dominantly across most mine site documentation. This category included a range of controls including ‘Manage fatigued individual’ (e.g., Fatigue rooms - when workers sent off site due to fatigue), ‘Journey management plans’ (e.g., CMW to ensure evidence in Journey Management Plan is maintained), and ‘Role of supervisor’ (e.g., Additional break or task rotation if fatigue issues are reported or identified in consultation with Supervisors). ‘Manage fatigued individual’ and ‘Journey management plans’ were the most frequently implemented preventative controls, and predominantly featured procedural controls. The role of the supervisor as a monitor of worker performance and decision maker to mitigate against negative impact of fatigue on performance emerged as an important feature.

‘Individual and non-work factors’ was the next most frequently identified category to emerge from the documentation, though fewer organisations offered examples of this control category. The majority of controls were identified in the ‘Build corporate, workforce, family and community awareness regarding factors that influence individual sleep’ (e.g., Medication declaration form - over the counter medication and prescription medication; All coal mine workers have a responsibility to present fit for work, monitor levels of alertness and obtain adequate sleep so as to not create an unacceptable risk.). However, the second category, ‘Develop, implement and monitor corporate programs that address non-work factors that influence fatigue’, quite importantly included employee access to EAP and worker support programs (e.g., Workers seek support through internal or external services (supervisor, EAP, mates in mining)). This is important as EAP is a legal requirement; however, it is not known if: a) it is being used, b) when used, it is useful, and c) whether the system companies have in place is effective.

Documentation provided by organisations also covered the categories of ‘Work environment conditions’ (e.g., Accommodation village provides gym and healthy food options; Accommodation will be made available to allow rest periods for persons commuting long distances at the beginning and end of rosters) and ‘Mental and physical work demand during shift’ (e.g., Job rotation for safety critical tasks and/or monotonous work and/or heat and other environmental conditions; Fixed / mobile plant induces or catalyses - Vibration matting to reduce vibration) to a lesser extent.

Overall, the suite of controls organisations have in place to manage fatigue is quite extensive ranging from roster and task design, through accommodation design and management, to controls to manage fatigue once detected in the work environment. However extensive the control types, they are largely procedural or soft in nature. There are significantly less practical or hard controls identified and implemented by all of the organisations that volunteered in this part of the review. These results indicate that controls that offer the lowest level of protection and reliability have been identified and implemented by the majority of organisations in this study. It is not known why this is the case. This may be for several reasons including cost of implementation or not knowing what types of hard controls exist for fatigue management.

The hierarchy of controls is well established. Controls that either eliminate the hazard and risks associated with it, and those that reduce the risk via substitution, isolation or engineering are recognised as being most effective at enhancing safety. Further work would be beneficial exploring why organisations are implementing lower order risk controls to manage fatigue and how they may be supported to implement controls that offer higher protection and reliability. However, one encouraging development that will be discussed in the summary case studies presented in the gap analysis section below is the use of fatigue detection technology by Glencore and others.

**Table 7.** Detailed summary of the number of organisational controls against the Riskgate categories

| | | Company 1 UG - Coal DIDO - Village | | Company 2 OC - Coal DIDO - Village | | Company 3 OC - Coal DIDO - Village | | Company 4 OC – Coal DIDO – Village | | Company 5 Corporate documents | | Company 6 UG - Coal DIDO? | | Company 7 UG - Coal DIDO - village | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Procedural (Soft) Controls | Practical (Hard) Controls | Procedural (Soft) Controls | Practical (Hard) Controls | Procedural (Soft) Controls | Practical (Hard) Controls | Procedural (Soft) Controls | Practical (Hard) Controls | Procedural (Soft) Controls | Practical (Hard) Controls | Procedural (Soft) Controls | Practical (Hard) Controls | Procedural (Soft) Controls | Practical (Hard) Controls |
| Work scheduling, planning and travel | Refer to guidance documents | 2 | 0 | 0 | 0 | 2 | 0 | 2 | 0 | 4 | 0 | 0 | 0 | 1 | 0 |
| | Roster design | 5 | 0 | 13 | 0 | 11 | 1 | 9 | 3 | 12 | 1 | 7 | 0 | 3 | 0 |
| | Implement fatigue management plan | 6 | 0 | 5 | 0 | 11 | 0 | 3 | 0 | 5 | 0 | 1 | 0 | 8 | 0 |
| | Work-related travel considerations (daily commute, and commute at start/end of cycle for non-residential workforce) with consideration for local factors (e.g. school bus times) | 0 | 2 | 1 | 1 | 0 | 3 | 0 | 2 | 2 | 0 | 0 | 0 | 1 | 0 |
| | Additional roster design considerations to manage shift work, particularly night shift | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Supervision and interaction during shift | 1 | 0 | 0 | 0 | 2 | 0 | 7 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| | Roster design to consider type of work and adequate rest breaks between consecutive shifts and shift blocks | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| | Specific consideration of fatigue impacts of salaried workers | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Work environment conditions | Appropriate accommodation for long distance commuting (FIFO, DIDO, etc.) | 0 | 1 | 0 | 1 | 3 | 1 | 4 | 2 | 2 | 1 | 0 | 0 | 0 | 0 |
| | Appropriate on-site facilities for all workers | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| | Exposure to noise, vibration, thermal extremes - heat, cold, humidity | 1 | 0 | 0 | 0 | 3 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 |
| Mental and physical work demands during shift | Consider mental and physical task characteristics in design of work | 2 | 0 | 0 | 0 | 1 | 0 | 1 | 2 | 3 | 5 | 0 | 1 | 0 | 1 |
| Individual and non-work factors | Build corporate, workforce, family and community awareness regarding factors that influence individual sleep | 1 | 0 | 1 | 0 | 5 | 0 | 6 | 0 | 6 | 0 | 2 | 1 | 2 | 0 |
| | Develop, implement and monitor corporate programs that address non-work factors that influence fatigue | 0 | | 0 | 0 | 1 | 0 | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| Failure to identify fatigue | Identification of fatigue prior to shift | 0 | 0 | 1 | 0 | 1 | 0 | 3 | 0 | 2 | 0 | 0 | 0 | 1 | 0 |
| | Role of supervisor | 1 | 0 | 1 | 0 | 3 | 0 | 1 | 1 | 3 | 0 | 0 | 0 | 1 | 0 |
| | Fail-to-safe design | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Manage fatigued individual | 3 | 1 | 0 | 5 | 4 | 0 | 2 | 1 | 2 | 0 | 0 | 0 | 0 | 1 |
| | Consider using fatigue detection technology | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 |
| | Risk-based task assessment and reassignment where necessary | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| | Performance management | 0 | 0 | 0 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Provision of suitable accommodation pre/post shift | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Company provided workforce transportation | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Journey management plans | 1 | 0 | 2 | 0 | 6 | 0 | 8 | 0 | 2 | 0 | 0 | 0 | 2 | 0 |
| | Community awareness programs | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

# 3. Part 1B – Incident data analysis

## 3.1 Background

Fatigue is a factor that has been linked to performance decrements in the minerals industry in Australia. Yet, measuring its direct contribution to injuries and illnesses in the workplace is notoriously difficult. One approach, at least as it relates to injury, is to retrospectively compare the safety performance outcomes of groups of employees whose work arrangements are more or less likely to provoke fatigue. Organisational, situational, and individual factors of course confound the relationship between roster design, fatigue and numbers of injuries/incidents, and are difficult to control. They include the complex nature of rostering and/or long-distance commuting arrangements at site level, differences between mining types (coal, metalliferous, quarrying; surface, underground), the quality of data held in available incident reporting systems, and 'healthy worker' effects.[11]

The research framework used here has taken another approach to analyse incident data that provides a snapshot of how mines in Australia are reporting fatigue-related events to regulatory agencies. One, that the authors believe, is more in keeping with the aims of the project, is to analyse incident data and related statistics to assist in understanding fatigue as a hazard. Also, to consider if fatigue is reported as a causal agent for incidents. The analysis has collated and reviewed notifiable incidents held by Queensland (2011-2021), New South Wales (2018-2022) and West Australian (2010-2020) mining regulatory bodies, where fatigue or a fatigue symptom (e.g., microsleep) has explicitly been cited by companies as contributing to an incident. It explores the data to determine how the industry describes fatigue and the job and mine types where fatigue events more commonly occur, and the category of incident, consequence and controls that typically characterise them. More comprehensive access to the Queensland dataset has allowed some simple tabulation of shift and shift cycle differences with incident numbers.

By reviewing the incident data in this way, this report seeks to understand if fatigue is a contributing factor to incidents, and if so what type of incidents? Also, to determine how it

[11] A phenomenon whereby a selection bias exists for workers relative to the general population, due to the fact that they must be relatively healthy in order to be employable in a workforce (Li and Sung, 1999). This is particularly the case for workers whose employment is based on an initial medical examination and then regular follow-ups – as is the case for many mining employees.

is being measured – what fatigue symptoms are more likely to be identified by industry and reported as contributing to events. For example, if an incident occurs on the last hour of the first shift back after leave, do sites report this as evidence to support a fatigue event? In this way, the current capacity of the industry to capture and report fatigue-reported events is gauged. It may also enable the identification of gaps in reporting – where education may be required to give sites the ‘know how’ to identify less direct symptoms of fatigue.

In comparing the data between the States, it is important to recognise the different sizes of the mining populations in each state.  The table below (Table 8) lists the approximate number of workers in the key sectors in the three major mining states sourced from the latest State Mining Authority published information.

**Table 8**. Mine worker numbers by State and sector

| | Queensland | New South Wales | Western Australia |
|---|---|---|---|
| **Open cut Coal** | 30,585 | 16,810 | 1,002 |
| **Underground Coal** | 6,011 | 7,109 | 0 |
| **Open cut Metal** | 6,459 | 3,432 | 130,553 |
| **Underground Metal** | 5,745 | 4,054 | 12,174 |
| **Quarrying** | 1,548 | 2,221 | Not available |

## 3.2 Queensland data

The dataset that forms the basis of the Queensland results was provided by Resources Safety and Health Queensland (RSHQ) (the Qld Resources Regulator). It is a subset of all notifiables reported by mines and quarries throughout Queensland between 2011 to 2021. All mines and quarries are required to provide to RSHQ notification and provision of information regarding deaths, serious accidents, high potential incidents, and diseases as per Part 11 of the Mining and Quarrying Safety and Health Act 1999 and part 11 of the Coal Mining Safety and Health Act 1999.

The subset includes just fatigue-related events reported by all the mining sectors (coal, metalliferous, quarries) and mining types (open cut and underground). It was compiled by conducting a search of the wider dataset using the search terms: “fatigue”, “micro sleep”, “sleep”, “tired”, “night shift”, “roster”, and “commute”. It was manually checked by the RSHQ and the authors to remove irrelevant events, such as where fatigue was used in the context of aging equipment or infrastructure. The final subset of events for the eleven-year period, comprised 662 events. To get a general sense of the proportion of the total notifiable events this represents, we reviewed the available Queensland Mines and Quarries Safety Performance and Health Reports for a similar 11-year period and found there to be a total of about 26,000 events reported – being high potential incidents (22,500) and lost time injuries (3,500) only. While not exact, it does highlight that (reported) fatigue-related events likely make up a relatively small proportion of all HPIs and LTIs reported (~2.5%).

### 3.2.1 Summary of results - Qld

When numbers of fatigue-related incidents were split across the mining sector (coal, metalliferous, quarries; surface, underground), it was found that over 80% of incidents occurred on a coal mine (n= 540, 82%) and most of these were on surface coal mines (90%), see Table 9. Across coal and metalliferous mines, incidents mainly occurred on surface mines (84%) compared to underground mines, see Table 10. Further, over 80% of incidents occurred in vehicles and most of these were heavy vehicles (HVs: 85%, LVs: 13%, NMV: 1.5%), see Table 11. Over 90% of vehicle-related incidents occurred on surface mines. Of those vehicle incidents on surface mines 89% involved HVs, 10% involved LVs, and 1% involved non-mine vehicles (NMV).

Overall, a picture emerged from the results of the location and job type where nearly all of the incidents occurred, which was driving heavy vehicles on surface coal mines.

When comparing the number of fatigue-related incidents across years, there was an apparent drop in fatigue-related vehicle events in 2020 and 2021 compared to the previous nine years, see Tables 8-10 and Figure 1. In 2020 and 2021 the number of HV incidents dropped to 30 or below per year. Annual number of incidents in the previous nine years ranged from between 60 to 39. In future work, it would be of interest to determine if changes in controls to manage fatigue have contributed to this recent reduction in vehicle-related incidents.

**Table 9.** Number of notifiable, fatigue-related incidents reported to RSHQ categorised by mining sector, mine type and vehicle/non-vehicle involvement, 2011-2021.

| Year | Fatigue-related incidents | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | All fatigue incidents | Mining sector (x mine type) | | | | | | | Non-vehicle incidents | Vehicle incidents | Vehicle type | | |
| | | Coal | | Metalliferous | | | | Quarry | | | HV | LV | NMV |
| | | surface | UG | surface | UG | process | dredge | | | | | | |
| 2011 | 62 | 43 | 3 | 6 | 6 | 1 | 2 | 1 | 16 | 46 | 40 | 5 | 1 |
| 2012 | 69 | 42 | 6 | 16 | 3 | 0 | 0 | 1 | 8 | 61 | 49 | 12 | 0 |
| 2013 | 56 | 36 | 3 | 9 | 7 | 0 | 0 | 1 | 10 | 46 | 42 | 4 | 0 |
| 2014 | 64 | 49 | 8 | 5 | 2 | 0 | 0 | 0 | 12 | 52 | 47 | 2 | 3 |
| 2015 | 62 | 49 | 2 | 9 | 2 | 0 | 0 | 0 | 9 | 53 | 42 | 8 | 3 |
| 2016 | 52 | 43 | 4 | 3 | 1 | 0 | 0 | 1 | 7 | 45 | 39 | 5 | 1 |
| 2017 | 57 | 52 | 0 | 2 | 1 | 0 | 0 | 2 | 9 | 48 | 45 | 3 | 0 |
| 2018 | 79 | 65 | 6 | 4 | 2 | 0 | 0 | 2 | 10 | 69 | 60 | 9 | 0 |
| 2019 | 72 | 44 | 14 | 9 | 4 | 0 | 0 | 1 | 19 | 53 | 43 | 9 | 1 |
| 2020 | 46 | 36 | 3 | 4 | 3 | 0 | 0 | 0 | 10 | 36 | 30 | 6 | 0 |
| 2021 | 43 | 27 | 4 | 4 | 3 | 0 | 0 | 5 | 15 | 28 | 22 | 6 | 0 |
| 2011-2021 | 662 | 487 | 53 | 71 | 34 | 1 | 2 | 14 | 125 | 537 | 459 | 69 | 9 |

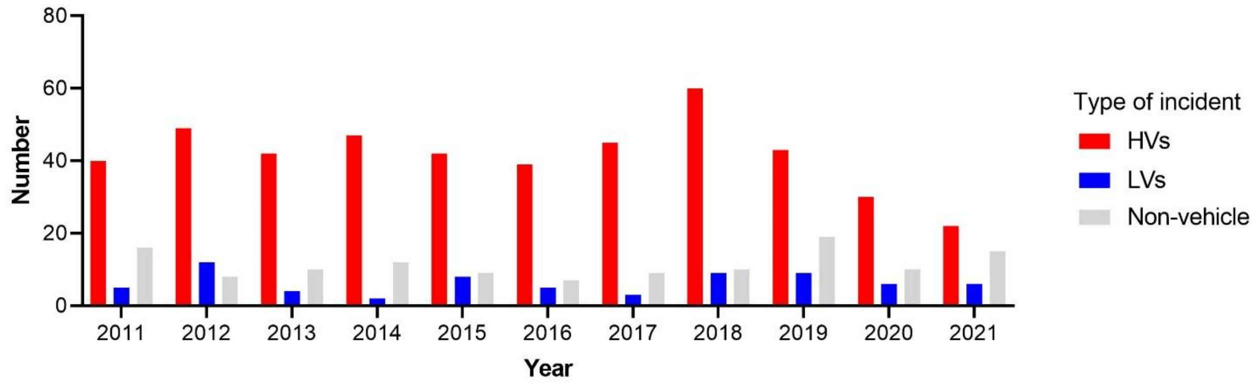
**Table 10.** Number of notifiable, fatigue-related vehicle incidents reported to RSHQ categorised by mining sector and type, 2011-2021.

| Year | Fatigue related incidents – vehicles only | | | | | |
|---|---|---|---|---|---|---|
| | All fatigue incidents | Mining sector (x mine type) | | | | |
| | | Coal | | Metalliferous | | Quarry |
| | | surface | UG | surface | UG | |
| 2011 | 46 | 38 | 2 | 5 | 0 | 1 |
| 2012 | 61 | 42 | 2 | 15 | 2 | 0 |
| 2013 | 46 | 36 | 1 | 4 | 5 | 0 |
| 2014 | 52 | 44 | 3 | 3 | 2 | 0 |
| 2015 | 53 | 45 | 0 | 7 | 1 | 0 |
| 2016 | 45 | 39 | 1 | 3 | 1 | 1 |
| 2017 | 48 | 44 | 0 | 1 | 1 | 2 |
| 2018 | 69 | 62 | 3 | 4 | 0 | 0 |
| 2019 | 53 | 41 | 6 | 3 | 3 | 0 |
| 2020 | 36 | 32 | 1 | 1 | 2 | 0 |
| 2021 | 28 | 25 | 0 | 3 | 0 | 0 |
| 2011-2021 | 537 | 448 | 19 | 49 | 17 | 4 |

**Table 11.** Number of notifiable, fatigue-related vehicle incidents in surface mines only reported to RSHQ categorised by mining sector and vehicle type, 2011-2021.

| Year | Fatigue related incidents – vehicles in surface mines only | | | | | | |
|---|---|---|---|---|---|---|---|
| | All fatigue incidents | Mining sector x Vehicle type | | | | | |
| | | Coal surface | | | Metalliferous surface | | |
| | | HV | LV | NMV | HV | LV | NMV |
| 2011 | 43 | 35 | 3 | 0 | 4 | 1 | 0 |
| 2012 | 57 | 36 | 6 | 0 | 11 | 4 | 0 |
| 2013 | 40 | 35 | 1 | 0 | 3 | 1 | 0 |
| 2014 | 47 | 42 | 2 | 0 | 3 | 0 | 0 |
| 2015 | 52 | 39 | 5 | 1 | 3 | 3 | 1 |
| 2016 | 42 | 35 | 3 | 1 | 3 | 0 | 0 |
| 2017 | 45 | 42 | 2 | 0 | 1 | 0 | 0 |
| 2018 | 66 | 56 | 6 | 0 | 4 | 0 | 0 |
| 2019 | 44 | 38 | 2 | 1 | 3 | 0 | 0 |
| 2020 | 33 | 28 | 4 | 0 | 1 | 0 | 0 |
| 2021 | 28 | 21 | 4 | 0 | 1 | 2 | 0 |
| 2011-2021 | 497 | 407 | 38 | 3 | 37 | 11 | 1 |

**Figure 1.** Number of vehicle (HV, LV) and non-vehicle, fatigue-related incidents 2011 – 2021 (QLD)




There were five types of incidents in the fatigue-related dataset:

- High potential no lost time,
- High potential lost time,
- Lost time,
- Serious accident, and
- Non-reportables.

Over 85% of incidents were categorised as ‘high potential no lost time incidents’ (n=569, 86%), see Table 12. This pattern was evident for vehicle-related incidents, but not for non-vehicle incidents, where there was a relatively even split between high potentials and lost time injuries.

Non-vehicle incidents, which made up nearly 20% of all fatigue-related incidents in the dataset tended to be workshop/maintenance related incidents involving manual tasks. Events were due to an error or long-term repetitive movement, sustained or awkward posture, and exposure to vibration. There were also slips, trips and falls. Examples of these incidents are given below with quotes taken from different responses related to each incident:

High potential no lost time/error:

- "Operator was cleaning a Normet Spraymec after shotcrete spraying a head underground when the boom began lifting without operator input and struck a cab mounted light before the operator could isolate the machine. Remote control box not 100% waterproof. Control box was sprayed with oil and water as part of the cleaning process. Operator new to camp and not getting enough sleep."

High potential lost time/error:

- "At approx 0015 hrs the operator informed the loader driver that he was going to test the temperature of the jaw crusher bearing of crusher of the (identifying information) plant situated at the ROM/Hardstand. The operator decided to test the temperature by hand. the operator had to lift the large rubber protective cover in order to access the area. the operators fingers were lacerated/crushed between a balancing plate and the back of the jaw as he attempted to feel the surface temperature with his hand while the machine was running. The operator decided to use a hand to feel for temperature rather than using the provided temp gun. There had not been a handover to the oncoming crew and the operator failed to follow the tag and isolate SOP. The operator confirms he has displayed a risk taking mentality and a disregard for his own safety. The worker also states he had only 1 hours sleep prior to commencing his first night shift."

Lost time/slips, trips and falls:

- "A Cultural Heritage Field Officer tripped and injured their knee whilst undertaking a site survey. Incident happened at end of day where involved person had walked much further than they were used to. Fatigue."
- "Shoulder injury slip from stairs on rear dump truck. On nightshift on (date) at 2230hrs, an operator slipped on the stairs of the rear dump 973 causing him to fall backward. His right arm went between the handrail and grill of the truck causing a small cut on his elbow and shoulder pain. Poor housekeeping- loose rock on stair. Surface gradient conditions and rocks. Hazard analysis failed to identify the hazard. Fatigue- working on night shift. Visibility- occurred on night shift.

Lost time/ manual tasks:

- “Operator was doing excessive digging on his last night shift (date) and afterwards felt that his back was sore.  Monitored on days off and reported to Supervisor on first day shift that his back soreness had not improved.  Taken to the doctor on (date).  The doctor advised that the operator should not work at all from (dates) - LTI and modified duties from (dates). Rushing due to operational requirements, fatigue due to manning levels (dual roles).”
- “The operator experienced back pain lifting 20kg Anfo bags repetitively over a three day period. The anfo hoist was unserviceable which is why the anfo bags were manually handled to load the kettle. The operator was fatigued from the repetitive strain of lifting 20kg Anfo bags from floor to above head height over a three day period
- “Shoulder injury sustained over time from maintenance duties. Fatigue.”

In comparison to non-vehicle fatigue related incidents, vehicle incidents are mostly high potential incidents with no lost time – near misses. When reviewing the narratives associated with each event, nearly all vehicle-related incidents included information about vehicle operators in surface mine having a brief microsleep or falling asleep and then hitting a bund or windrow, which likely mitigated more serious outcomes. In the underground environment, fatigued operators were more likely to collide with ribs and walls. The quotes below are taken from the narratives of incidents in the dataset and provide examples of these occurrences for the various mine and vehicle types.

- Coal/Surface/HV:
    - “Operator had a microsleep and made contact with centre bund. No injury and minor damage to truck.”
    - “Micro Sleep / Uncontrolled movement of a fully loaded Cat 793F rear dump truck. An operator (contractor) had a microsleep and veered off a haul rd and struck a 2m windrow. The truck came to rest straddled over the windrow, No Injuries. D&A testing done and clear.”

    - “Operator has left with a full load, after coming around the bend toward bridge, operator has felt the truck hit the windrow, and corrected the truck. Operator has pulled up safely and inspected truck, noticed stairs were damaged and notified supervisor. In Operators statement he has said that he had a suspected micro sleep.”
    - “Microsleep. A fatigued operator experienced a microsleep while operating a loaded rear dump truck and veered to the left-hand side of the road running up the windrow before waking and steering the truck back onto the haul road.”
    - “CMW has fallen asleep while operating in a waste circuit on the way to a dump resulting in truck drifting approx. 100m to the left and coming to rest against a bund. CMW was on first shift of a 5 day night shift rotation.”
    - “CAT785 was loaded travelling up a ramp when operator had a micro sleep. The truck failed to take a right hand hairpin corner and travelled straight ahead contacting the bund. No injuries sustained.”
- Coal/Surface/LV:
    - “LV was being driven out of the pit, but operator fell asleep and struck a windrow causing the LV to roll to its side.”
    - “Micro sleep - loss of control - Two CMW were travelling in a ute when the driver had a micro sleep and ran up a berm 1.5 mtrs.  No roll over and control regained when electrician woke up.”
    - “Light Vehicle contacted guard rail on access road when operator had a suspected microsleep.”
- Coal/Underground/HV:
    - “The operator has taken his eyes off the road when driving out of the mine after completing a night shift. A micro sleep may have occurred. The vehicle has veered into the side of the road and has made strong contact with rib bolts protruding into the roadway.”

- Coal/Underground/LV:
    - “Loss of control of vehicle - ERZC driving drift runner down 1:7 drift fell asleep and run into rib.”
    - “Collison - While traveling out of the mine at the end of shift the CMW operating has had a micro sleep. This has resulted in the PJB contacting the rib.”
- Metalliferous/Surface/HV:
    - “Whilst driving up the ramp at the speed of approx.12 km/h, driver had a micro sleep and found truck driving into the windrow when he woke up he stopped the truck immediately and reported incident. No injuries or damage to the truck.”
    - “Operator of dump truck was driving loaded truck up waste dump ramp, at end of N/S had micro sleep. Truck bellied out on windrow with drivers side wheels on one side of windrow and offside wheels on the other.”
- Metalliferous/Surface/LV:
    - “Person rolled light vehicle after micro sleep while driving. Ran up windrow. No Injury.”
    - “LV was being driven out of the pit, but operator fell asleep and struck a windrow causing the LV to roll to its side.”
    - “Worker fell asleep while operating 14 seater bus and has woken up when bus contacted windrow-Suspected fatigue related.”
- Metalliferous/Underground/HV:
    - “Uncontrolled movement - no injuries - Operator of TH663 truck has fallen asleep whilst tramming on the decline and come into contact with wall.”
    - “Truck operator competing first night shift of the swing was transporting a final load of material for the shift to the surface when the operator has potentially had a micro sleep which resulted in the loaded truck travelling up the decline at a speed of approximately 10 kph making contact with the wall.

> Actual consequences of the impact with the wall was damage to the cab of the truck."

A key result of our incident data analysis is that most fatigue-related incidents occur in vehicles (81%) and when describing these incidents to the Regulator, sites commonly use the term 'micro sleep'. It suggests that the industry is knowledgeable about identifying fatigue symptoms for vehicle operators. For the nearly 20% of notifiable fatigue-related incidents that are reported occurring in other mining jobs, it appears that sites are less sure about fatigue symptoms. Fatigue is reported as contributing to error, musculoskeletal pain and slips, trips and falls, but it is often an assumption that appears to be made based on a shift characteristic (e.g., working night shift or late into the shift, or the first shift back after leave) and/or an environmental factor (e.g., hot weather). In these narratives – compared to the vehicle incidents, it was more a case of, 'it could be fatigue'. Perhaps more training or education on symptoms of fatigue across different job types is warranted. For example, symptoms of physical and mental weariness and exhaustion - irritability, impaired thought processes, inability to make decisions, inability to concentrate on daily tasks, inability to cope, forgetfulness and poor motivation. This may in turn assist in better detection of fatigue across the workforce.

**Table 12.** Number of notifiable, fatigue-related incidents reported to RSHQ categorised by incident type, 2011-2021.

| Year | Fatigue related incidents | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Non-vehicle incidents | | | | | Vehicle incidents | | | | |
| | High potential no lost time | High potential lost time | Lost time | Serious accident | Non-reportable | High potential no lost time | High potential lost time | Lost time | Serious accident | Non-reportable |
| 2011 | 6 | 1 | 9 | 0 | 0 | 46 | 0 | 0 | 0 | 0 |
| 2012 | 1 | 1 | 6 | 0 | 0 | 58 | 0 | 3 | 0 | 0 |
| 2013 | 6 | 0 | 3 | 1 | 0 | 45 | 0 | 0 | 0 | 1 |
| 2014 | 7 | 1 | 3 | 1 | 0 | 48 | 2 | 1 | 0 | 1 |
| 2015 | 4 | 0 | 5 | 0 | 0 | 48 | 0 | 2 | 0 | 3 |
| 2016 | 4 | 1 | 2 | 0 | 0 | 43 | 1 | 1 | 0 | 0 |
| 2017 | 3 | 0 | 4 | 2 | 0 | 45 | 0 | 2 | 0 | 1 |
| 2018 | 5 | 0 | 3 | 0 | 1 | 65 | 2 | 0 | 1 | 1 |
| 2019 | 12 | 0 | 7 | 0 | 0 | 52 | 0 | 0 | 0 | 1 |
| 2020 | 5 | 0 | 3 | 2 | 0 | 36 | 0 | 0 | 0 | 0 |
| 2021 | 4 | 1 | 8 | 2 | 0 | 26 | 2 | 0 | 0 | 0 |
| 2011-2021 | 57 | 5 | 53 | 8 | 1 | 512 | 7 | 9 | 1 | 8 |

*Note*: in 2018 there was one fatality in the non-vehicle incidents category which was deemed natural causes (See ID# 138901, 22/01/2018).

*Shift information*:

Information in the dataset was used to calculate whether a vehicle operator was on a day or night shift. There were 459 incidents that could be categorised according to whether the operator was working day or night shift when an incident occurred. It was found that more than two thirds of the total number of vehicle-related incidents occurred when operators were on night shift (n = 330, 72%), while less than 30% of incidents occurred during day shift (n = 129, 28%).

Information reported in the dataset was used to calculate hour into shift that an incident occurred. This was then split by vehicle type and type of shift (day/night). In this way, periods when incident prevalence increased could be compared across day and night shifts and between heavy and light vehicles. As shown in Figure 2, there appears to be a difference in the critical periods in night and day shifts when incidents are more prevalent, which is earlier in day shift than night shift.

- The highest proportion of night shift incidents for vehicles occurred in the 11th (LVs 29% incidents) and 12th (HVs 27.5%) hours of the shift.
- The highest proportion of the day shift incidents in vehicles occurred for HVs in the 7th (14%) and 8th (15%) hours of the shift. For day shift LVs, the highest proportion of incidents occurred in the 7th hour (21%)
- These results were not confounded by differences in the durations of day and night shifts as duration of shift patterns were found to be similar across both shifts.

Three shift-related variables in the dataset (one an open field) were combined to identify common shift cycles, from which an exploration of fatigue accumulation effects might be identified.[12] This analysis was affected by missing data, for example, 33% of incidents in the open field question did not have a response. The most common roster cycle was found to be the “7-on,7-off” roster. However, just 73 incidents could be collated where operators were working this shift over the 11 years of the dataset. These were further subdividing to determine if operators were working night or day shifts at the time of the incident, which

[12] Variables were: Roster Pattern (open field), Shifts completed in current cycle prior to incident, Days in shift cycle.

reduced the dataset to 71. This subset of incidents were analysed to determine when incidents more commonly occurred on day and night shifts. As shown in Figure 3, the highest number of incidents for HV operators on night shift was day one, with 26% of all night shift incidents occurring. In comparison, the day with the highest number of incidents for day shift operators was day two, with 28% of all day shift incidents occurring. There was to some extent a midweek fatigue effect for both day and night shift operators – it occurred on day three for night shift operators and day four for day shift operators. Evidence did not support fatigue accumulation effects, as the number of incidents on the final two days for both day and night shift was relatively low.

**Figure 2.** Percentage of HV and LV incidents per hour into shift for day and night shift operators (2011 – 2021, n=441) (QLD)

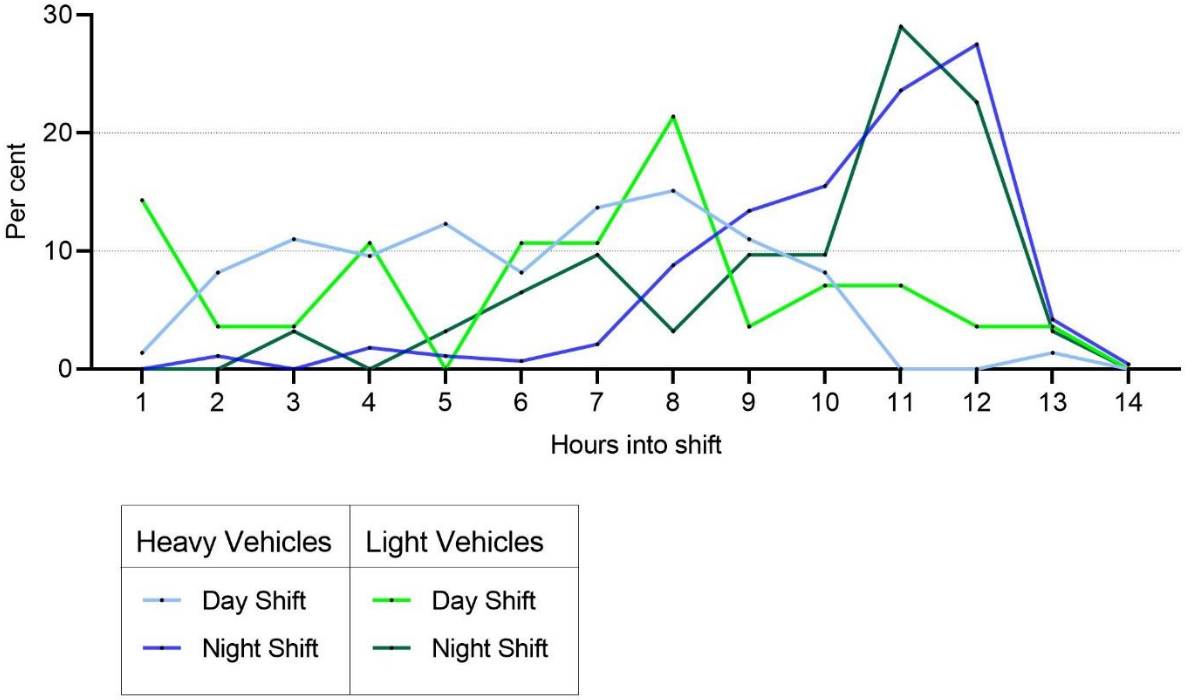
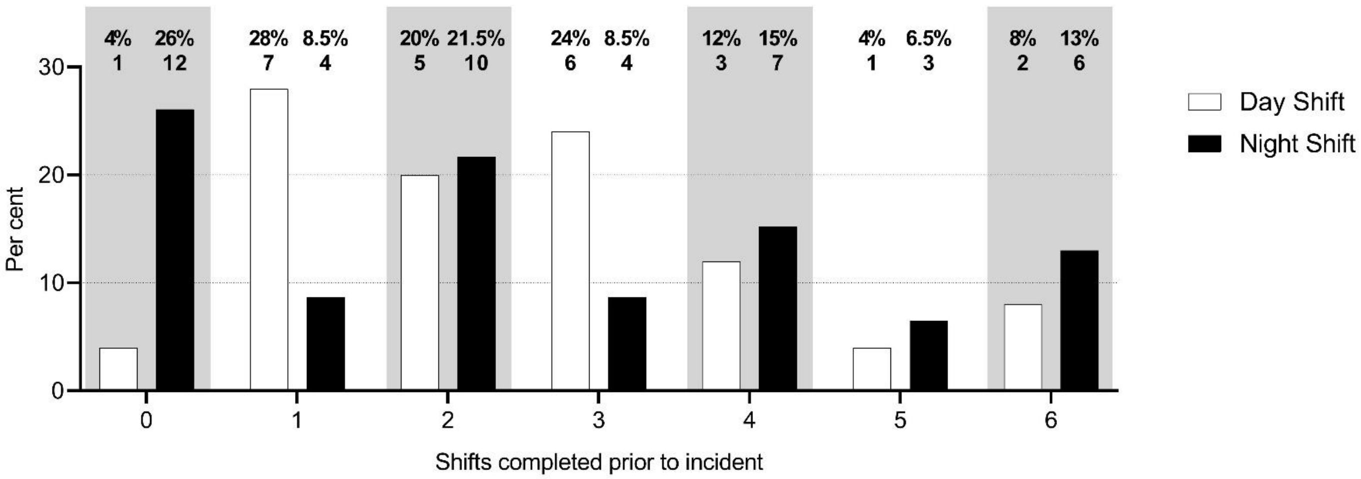



**Figure 3.** Percentage (and number) of vehicle only incidents that occurred in shifts prior to incident for the "7 on, 7 off" shift cycle, x night and day shift (2011 to 2021) (n=71)



## 3.3 New South Wales data

At the end of June 2022, we sought permission from the NSW Resources Regulator to access their fatigue-related Safety Incident Notifications for all mining sectors (coal, metalliferous, small mines) and mining types (open cut and underground) from 2018 to present; being the period that includes their introduction of a new taxonomy to categorise incidents.

Under the NSW *Work Health and Safety (Mines and Petroleum Sites) Act 2013* and Work Health and Safety (Mines and Petroleum Sites) Regulation 2014, the NSW Resources Regulator needs to be informed of a work-related death, injury, illness, dangerous incident or high-potential incident.

The Regulator sent us a dataset of 41 fatigue-related incidents. This represents a very small proportion of the total annual safety incident notifications received by the Regulator across this period. The Regulator receives about 2,000 notifications per year, as shown below. In the 4 ½ years that the current dataset spans, we estimate there were about 9,000 total incidents, so the fatigue related sample represents about 0.5% of that.

Annual number of NSW Safety Incident Notifications:

2017/2018[13]: 1,931

2018/2019[14]: 2027

2019/2020[15]: 2,120

2020/2021[16]: 2,061

---

[13] https://www.resourcesregulator.nsw.gov.au/sites/default/files/documents/rr-minesafety-annualactivityreport_2017-2018-web-optimised.pdf

[14] https://www.resourcesregulator.nsw.gov.au/sites/default/files/documents/rr-minesafety-annualactivityreport_2017-2018-web-optimised.pdf

[15] https://www.resourcesregulator.nsw.gov.au/sites/default/files/documents/annual-report-2019-2020.pdf

[16] https://www.resourcesregulator.nsw.gov.au/sites/default/files/2021-11/Resources-Regulator-Annual-Report-2021.pdf

### 3.3.1 Summary of results- NSW

Site based reporters used the following words to describe fatigue: micro sleep (n = 30), fatigue (n = 9), asleep (n = 6), sleep apnoea (n = 1), and stress (n = 2).

Incidents were initially examined to determine their frequency across different mine sector/types (coal, metals; open cut, underground), vehicles and non-vehicle incidents, and type of vehicle. The results are shown in Table 13. They show that 95% of incidents involved the operation of a vehicle (39 of 41 incidents) and 82% of these involved HVs (32 of 39). Also, 85% of incidents occurred in open cut coal mines (35 of 41 incidents). There were just two non-vehicle incidents in the dataset.

The annual numbers of vehicle-related, fatigue incidents show a considerable fall in incident numbers from 2018 to 2019, after which numbers remained relatively low across time, see Table 12. In 2018, there were 21 incidents and then it dropped to nine incidents in 2019. It is difficult to determine the significance of this drop due to there only being four and a half years of data. But the authors were told anecdotally by the Regulator that company use of eye camera technology in HVs had lowered numbers of fatigue incidents.

**Table 13**. Number of notifiable, fatigue-related incidents reported to the NSW Resources Regulator categorised by mine type and vehicle/non-vehicle involvement, 2018-2022.

| Year | Fatigue related incidents | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | All fatigue incidents | Mine sector/type | | | | | Non-vehicle incidents | Vehicle incidents | Vehicle type | | |
| | | Coal OC | Coal UG | Coal Proc | Metals UG | Metals Proc | | | HV | LV | NMV |
| 2018 | 22 | 18 | 2 | 1 | 1 | 0 | 1 | 21 | 17 | 4 | 0 |
| 2019 | 9 | 8 | 0 | 0 | 0 | 1 | 0 | 9 | 8 | 0 | 1 |
| 2020 | 5 | 5 | 0 | 0 | 0 | 0 | 1 | 4 | 4 | 0 | 0 |
| 2021 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| 2022* | 4 | 2 | 1 | 0 | 1 | 0 | 0 | 4 | 2 | 2 | 0 |
| 2018-2022 | 41 | 35 | 3 | 1 | 2 | 1 | 2 | 39 | 32 | 6 | 1 |

Note: * Jan to June, 2022, OC=open cut, UG=underground, Proc=Processing, HV=heavy vehicle, LV=light vehicle, NMV=non-mine vehicle.

The new taxonomy the NSW Resources Regulator is using to collect and categorise notifiables, allowed us to confidently categorise outcome types and sub-types, see Tables 12 - 14. About half of the vehicle-related incidents (20 of 39) resulted in some type of collision, with most of them (n=15, 75%) being single vehicle collisions. Of the single vehicle collisions, 12 of them (80%) involved colliding into a windrow or bund in the open cut environment. The one underground single vehicle collision involved running into a rib. There was one non-mine vehicle single vehicle incident, which is cited below.

Single vehicle collisions

- Open Cut/HV:
  - “(Vehicle Number) drove onto a windrow when the operator experienced a microsleep. The truck straddled the windrow parallel with the haul road before coming to rest. Beyond the windrow there was a crest to the mining excavation approximately one truck width from the edge of the truck.”
- Underground/HV:
  - “The N/S crew were travelling out of the mine at the end of shift using (Vehicle Number). The transport has contacted the LH rib and rib bolt in the transport road causing damage to the LH fender, LH cabin post and shattering the LH windscreen.”
- Non-Mine Vehicle:
  - “It would appear an operator has suffered a XX when leaving site in his own vehicle. He has left the road & traveled approximately 250m. He has driven over a guide post, sapling & a large poly pipe before coming to rest against a large tree. The impact with the tree did not cause the airbags to be set off. He could not remember anything about the accident. He has been taken to hospital by ambulance in a stable condition. Certificate received dated (Date) has stated that the incident occurred due to "Undiagnosed and untreated obstructive sleep apnoea".

There were seven fatigue incidents that resulted in *unintended movement*, an example is given below.

“The operator of laden Cat 793 truck 660 has experienced a micro-sleep while travelling down XX mine ramp (500 m).  The truck was seen by another driver to lose control of the truck - travelling over speed. The other driver called on the two way and managed to wake him up, the operator managed to regain control on a flat part of the roadway.

The operator commenced shift at 5:00 am. The driver was known to be diabetic and was referred for medical review by the nurse. The truck operator used the retarder to stop the truck.”

Numbers of fatigue related incidents were also split according to consequence. Nearly 60% of incidents (24 of 41) were classified as having the potential to cause potential injury or illness and all but one of these involved operations of a vehicle. Eight of 41 incidents (20%) caused damage to equipment or plant (i.e., minor damage, moderate damage, and unspecified damage).

There was one incident that was classified as having a mental health consequence, another as resulting in illness, and another entrapment. They are quoted below.

- Mental Health:

“Worker claims he is stressed at work, not able to concentrate, states he was bullied at work, not able to manage at home and stressed, and not able to sleep.”

- Illness:

“It would appear an operator has suffered a XX when leaving site in his own vehicle. He has left the road & travelled approximately 250m. He has driven over a guide post, sapling & a large poly pipe before coming to rest against a large tree. The impact with the tree did not cause the airbags to be set off. He could not remember anything about the accident. He has been taken to hospital by ambulance in a stable condition. Certificate received dated (Date) has stated that the incident occurred due to "Undiagnosed and untreated obstructive sleep apnoea".

- Entrapment:

A loaded Komatsu 830E was queued on a ramp.  The operator has had a micro sleep and the truck has started to roll backwards.  He has then hit the brake/accelerator and the truck has sat on the rear of the tray resulting in the operators cab being raised in the air, the front wheels were estimated to be 4m from the ground. The operator remained "cool, calm and collected".  The truck has been recovered, taking 3 hours to allow the operator to exit the truck."

- Unspecified injury:

At about 0530hrs on 10 XX (operator) was traveling on inpit road when she allegedly had a microsleep. The light vehicle she was driving has rolled/overturned onto its side. following the incident the operator has activated the site emergency procedure and has been assessed by onsite paramedics. The operator is currently under observation at the mine and is expected to be released imminently."

**Table 14**. Number of notifiable, fatigue-related incidents reported to the NSW Resources Regulator categorised by outcome type and sub-type, 2018-2022.

| Year | Fatigue-related incidents | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Vehicle incidents | Incident type | | | | | | | | | |
| | | Collision | | | | | Other unintended action / loss of control | | | | Not categorised |
| | | Single vehicle | Head on | Rear end | Manoeuvring | Near miss | Rollover | Unintended movement | Failure to stop | Immobilisation | |
| 2018 | 21 | 9 | 1 | 1 | 0 | 0 | 2 | 2 | 0 | 1 | 5 |
| 2019 | 9 | 2 | 0 | 0 | 1 | 1 | 0 | 3 | 2 | 0 | 0 |
| 2020 | 4 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 |
| 2021 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2022* | 4 | 2 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| 2018-2022 | 39 | 15 | 1 | 1 | 2 | 1 | 3 | 7 | 3 | 1 | 5 |

Note: * Jan to June, 2022,

**Table 15.** Number of notifiable, fatigue-related incidents reported to the NSW Resources Regulator categorised by consequence, , 2018-2022.

| Year | Fatigue related incidents | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | All fatigue incidents | Consequence | | | | | | | | |
| | | Illness | Potential injury or illness | Unspecified injury | Entrapment | Mental disease | Minor damage | Moderate damage | Unspecified damage | Not categorised |
| 2018 | 22 | 0 | 13 | 1 | 1 | 0 | 1 | 1 | 0 | 5 |
| 2019 | 9 | 1^ | 7 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 2020 | 5 | 0 | 3 | 0 | 0 | 1 | 1 | 0 | 0 | 0 |
| 2021 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2022* | 4 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 1 | 0 |
| 2018-2022 | 41 | 1 | 24 | 1 | 1 | 1 | 6 | 1 | 1 | 5 |

Note: * Jan to June, 2022, ^sleep apnoea

## 3.4 Western Australia data

The Western Australia Government's Department of Mines, Industry Regulation and Safety make available to the public for industry awareness, mining incidents reported to them from mining companies since 2010. This resource is updated regularly and can be interrogated, viewed and the results exported to a Microsoft Excel file for analysis via the Safety Regulation System (SRS).[17]

The authors downloaded all of the incidents classified as *potentially serious occurrences* between 2010 and 2020 which included 5148 incidents. A potentially serious occurrence or incident is any event at a mine or exploration site that the manager considers had the potential to cause serious injury or harm to health, even though no injury or harm has in fact occurred. The dataset was then searched to select fatigue incidents using the terms: fatigue, asleep, micro (sleep) and tired. A subset of 89 fatigue-related incidents was identified, which represent 1.7% of all incidents. Each of the incidents were then read by two authors. The term 'micro sleep' occurred in 41 incidents, 'asleep' (as in fell asleep) occurred in 32 incidents, 'fatigue' in 24 incidents and 'tired' in two incidents.

The dataset is limited in that it only provides a serial number, incident date, a short narrative of varying quality, and whether the incident occurred in mining or exploration. Narratives were used to determine other variables such as mine type (surface, underground mines) and vehicle type (HVs, LVs, NMVs).

As shown in Table 16, of the fatigue incidents, 98% occurred in vehicles (n=87), and of these 55% occurred in HVs and 40% occurred in LVs. Eighty-four per cent occurred in surface mines, 7% occurred in underground mines, 7% occurred off-site. Examples of narratives for each of these are:

Surface Mine/HV:

- "A haul truck was travelling up an open pit ramp when the operator suffered a micro sleep with the truck veering to the left and contacting the windrow. No

[17] https://srs.dmp.wa.gov.au/SRS/Public/PublicationSearch?publicationTypeEnum=SummaryIndustryAwareness&_gl=1*ka343z*_ga*NTExMTM3Mzk1LjE2NTgyMDY2MjQ.*_ga_S1QYDDWVV5*MTY2MTUwNzU3MC4zLjEuMTY2MTUwODA2Ni4wLjAuMA..

one was injured. The operator brought the truck to a stop and notified a supervisor. An investigation was commenced.”

Surface Mine/LV:

- “The driver of a light vehicle (LV) lost control of the vehicle on an access road after falling asleep behind the wheel on night shift. The vehicle left the road and came to a stop ~ 10 m from the side of the road. The driver was uninjured and there was minor damage to the vehicle. The cause of the incident was fatigue.”

Underground Mine/HV:

- “The driver of an underground truck briefly fell asleep while tramming up the decline. The truck hit the left wall of decline. There was no injury, minor damage and a broken window to the truck.”

Underground mine/LV:

- “A driller’s offsider was driving a light vehicle (LV) in an underground mine when he fell asleep causing the LV to make contact with the wall of the decline. A preliminary investigation identified that the offsider was not fit for work.”

Of the fatigue related events in vehicles, 82% hit something which caused them to wake up or it stopped the vehicle. Sixty-one per cent of those that hit something, hit a safety barrier (Windrow: n = 33, Bund: n = 6, Centre Island: n = 2, Delineator: n = 2).

Time of day could not be determined for the majority of incidents. Only 11 incidents reported provided this information: night (9%, N=8) and day (3%, N=3).

**Table 16**. Number of notifiable, fatigue-related incidents reported to the WA Resources Regulator categorised by vehicle/non-vehicle involvement, 2010-2020.

| Year | Total incidences | Fatigue related incidents | | | | | |
|---|---|---|---|---|---|---|---|
| | | All fatigue incidents | Non-Vehicle | Vehicle | Vehicle type | | |
| | | | | | HV | LV | Non-mine vehicle |
| 2010 | 499 | 8 | 0 | 8 | 3 | 4 | 1^ |
| 2011 | 462 | 4 | 0 | 4 | 3 | 1 | 0 |
| 2012 | 439 | 10 | 0 | 10 | 5 | 5 | 0 |
| 2013 | 555 | 15 | 0 | 15 | 6 | 9 | 0 |
| 2014 | 543 | 10 | 0 | 10 | 6 | 4 | 0 |
| 2015 | 384 | 16 | 1 | 15 | 9 | 4 | 2* |
| 2016 | 409 | 6 | 0 | 6 | 4 | 2 | 0 |
| 2017 | 469 | 11 | 0 | 11 | 7 | 4 | 0 |
| 2018 | 589 | 2 | 0 | 2 | 2 | 0 | 0 |
| 2019 | 513 | 1 | 1 | 0 | 0 | 0 | 0 |
| 2020 | 286 | 6 | 0 | 6 | 3 | 2 | 1^ |
| 2010-2020 | 5148 | 89 | 2 | 87 | 48 | 35 | 4 |

*Note*. ^ personal vehicle, *bus

## 3.5 Summary comparison of Queensland, NSW and WA fatigue data

The current review has shown that fatigue is rarely reported as contributing to notifiable incidents in mining. We estimated that 0.5%, 1.7%, and 2.5% of all incidents reviewed from New South Wales (2018-2022), Western Australia (2010-2020) and Queensland (2011-2021), respectively, included fatigue or a related term (e.g. micro sleep, asleep, tired) in their incident descriptions/narratives. It is surprising, considering the 24-7 nature of mining operations that more fatigue-related incidents were not identified.

Directly comparing the Queensland, NSW and WA fatigue-reported data directly is problematic due to differing reporting systems, different mine environments etc. Equally, as seen earlier in Table 8, there are more workers employed in surface than underground mines across all three Australian States. But at a broader level, the picture emerging from all three states is that the majority of fatigue-reported incidents are:

- vehicle-related,
- are reported on surface mines, and
- occur when driving heavy vehicles.

Across jurisdictions, most of the fatigue-related incidents were single vehicle accidents most of which, fortunately, did not result in operator injury but often equipment damage. On that basis, incidents were mostly categorised as high potential incidents (near misses). Road barriers (windrows and bunds) were commonly found to prevent vehicles from running off roads in surface mines. Although less apparent in the narratives, it is likely that mine design strategies such as separate HV and LV roads plays an important role in mitigating more serious accidents. In underground mines fatigued operators tended to collide with ribs and walls. Operators often reported waking up after hitting a barrier. About 20% of incidents from the Queensland dataset were non-vehicle incidents and these tended to result in human error, slips, trips and falls; and musculoskeletal pains and strains.

Our extended analysis of the Queensland incidents showed that more incidents occurred in the last few hours of a shift, compared to earlier hours in the shift. Also, in a group of workers on a 7-day on, 7-day off roster arrangement, we found that more incidents occurred in the first few days back than in the later shifts. Two thirds of the total number of vehicle-related incidents occurred when operators were on night shift, while less than 30% of incidents occurred during day shift.

## 3.6 Comparison against road transport and workplace fatigue data

The analyses of fatigue-related mining incidents from Queensland, New South Wales and Western Australia (Sections 3.2 - 3.4) clearly shows that across jurisdictions, most incidents are being reported in the operation of heavy vehicles. In this section, the report examines that outcome in comparison with:

1. Fatigue data from a similar industry - Road Transport, and
2. Workplace fatigue data.

Fatigue-related, vehicle mining incidents were mainly captured from high potential incidents, very few of the incidents we reviewed resulted in lost time injuries.[18] A likely explanation for this, supported by evidence from the data, is that mines (compared to the road transport industry) are better able to control the environment in which their heavy vehicles operate. This includes road design and construction plans and traffic management systems. The former implements actions to both prevent incidents, such as segregated HV and LV roads and lighting; and to mitigate the consequences of incidents, such as the placement of bunds, windrows and centre delineators. Our findings robustly show the safety critical role they play in preventing HVs (and LVs) from falling over road edges or hitting other vehicles or infrastructure. Traffic management systems regulate speed, direction of travel, use of intersections and develop protocols for positive communications between vehicles.

It would be a mistake to assume from these results that operator fatigue is perfectly managed on sites. It appears that controls are in place to prevent or minimise the impacts of fatigue, particularly in single vehicle collisions. Fatigued operators driving heavy vehicles that interact with other types of vehicles, pedestrians and infrastructure in multiple scenarios remain a considerable risk. Evidence of the risk of fatigue is clearly shown in the results of the impact of fatigue in the transport industry, as shown in the section below.

Also included in this section is workplace fatigue data. Our data has primarily elicited findings concerning one job type – vehicle operators. Yet many other mine jobs operate under potentially fatigue triggering conditions, including: roster design arrangements, long distance commute arrangements, job characteristics (repetitive, monotonous, high job demands and time pressure), prolonged exertion (inc. repetitive movement, sustained or awkward posture, exposure to vibration), etc. All of which can have short- and long-term detrimental effects on safety and health. Yet we found only limited evidence here of fatigue contributing to other job type incidents. By reviewing more general workplace fatigue data we hope to better understand the extent to which fatigue could be contributing to safety incidents across sites.

---

[18] That is despite our fatigue-related datasets requested from QLD and NSW mining Regulators, including all notifiable incidents where fatigue or fatigue symptoms were reported by sites as contributing to the event.

### 3.6.1 Road transport

*1. Transport Accident Commission, Victoria*.

- Driving when tired is a contributing factor in between 16-20% of all road crashes in Victoria.
- Fatigue is a major cause of crashes in Victoria, around 30 people die each year and up to 200 people suffer serious injuries due to these types of crashes (5 year average).
- 37% of people admit to driving while tired

Source: https://www.tac.vic.gov.au/road-safety/staying-safe/tired-driving

*2. Transport for NSW:*

- From 2008 to 2016 there were a total of 532 fatal crashes involving fatigue, resulting in 583 fatalities, with fatigue accounting for 17 per cent of all fatalities over this period.
- From 2008 to 2015 there were a total of 6,321 serious injuries (matched to a police crash report) from fatigue related crashes, representing 12 per cent of all matched serious injuries over this period
- the percentage of total serious road trauma which involves fatigue has increased for fatalities, from 16 per cent to 21 per cent from 2008 and 2016.

Source: https://roadsafety.transport.nsw.gov.au/downloads/trauma-trends-fatigued-distracted-driving.pdf

*3. Worldwide.*

It is estimated that between 10% and 20% of all road crashes are fatigue-related.

Source: https://www.brake.org.uk/get-involved/take-action/mybrake/knowledge-centre/driver-fatigue

*4. Queensland centre for accident research and road safety.*

- Sleepiness contributes to 20-30% of all deaths and severe injuries on the road, similar to speeding and drink driving.

Source: https://research.qut.edu.au/carrs-q/wp-content/uploads/sites/296/2020/06/Sleepiness-and-fatigue-FINAL.pdf

*5. Queensland parliament.*

- In 2010, there were 30 fatalities as a result of fatigue related crashes within Queensland, representing 12% of the Queensland road toll
- In 2009, there were 45 fatal car crashes where fatigue was considered a contributing factor/characteristic, representing 13.6% of all road crash fatalities

Source: https://documents.parliament.qld.gov.au/tp/2013/5413T2572.pdf

### 3.6.2 Workplace

*National Safety Council (USA)*

- A systematic review conducted by Uehli (2014) of 27 research studies found that workers with sleep problems have a 1.62 times higher risk of injury than workers without sleep problems.
- The study also estimates that about 13% of work injuries can be attributed to sleep problems.

Source: https://injuryfacts.nsc.org/work/safety-topics/work-related-fatigue/ and

Other workplace fatigue studies are shown in Table 17 below.

**Table 17.** Other workplace fatigue studies

| Authors, title, and publication | Findings |
|---|---|
| Younan, L, Clinton, M, Fares, S, Jardali, FE, Samaha, H.<br><br>*The relationship between work-related musculoskeletal disorders, chronic occupational fatigue, and work organization: A multi-hospital cross-sectional study.*<br><br>J Adv Nurs. 2019; 75: 1667– 1677. https://doi.org/10.1111/jan.13952 | • Nurses from 39 hospitals completed self-reported questionnaires from June to September 2015. Descriptive statistics were used to summarize hospitals and nurses' characteristics, fatigue levels and prevalence, and type of musculoskeletal disorders. Linear and logistic regression analyses were used to identify correlational factors.<br>• 71.3% of participants reported a work-related musculoskeletal disorder in the previous 12 months, mainly back pain.<br>• The reported musculoskeletal disorders were significantly correlated with years of experience, nurse to patient ratios, and chronic occupational fatigue. |
| Frone MR, Blais A-R.<br><br>*Work Fatigue in a Non-Deployed Military Setting: Assessment, Prevalence, Predictors, and Outcomes.*<br><br>International Journal of Environmental Research and Public Health. 2019; 16(16):2892. https://doi.org/10.3390/ijerph16162892 | • Study assessed the prevalence of work fatigue in a non-deployed setting, and explored several potential predictors and outcomes of work fatigue in this setting.<br>• Data came from a large national probability sample (N = 1375) of non-deployed Royal Canadian Air Force military personnel.<br>• Physical, mental, and emotional work fatigue were positively associated with workplace cognitive failures and work-to-family conflict. |
| Techera, U., Hallowell, M., Stambaugh, N., & Littlejohn, R. (2016).<br><br>*Causes and Consequences of Occupational Fatigue: Meta-Analysis and Systems Model.*<br><br>Journal of Occupational and Environmental Medicine, 58(10), 961–973. https://www.jstor.org/stable/48501301 | • A comprehensive and systematic review of existing literature was undertaken and the first statistical meta-analysis of occupational fatigue conducted.<br>• The drivers of fatigue with the greatest effect sizes include sleep deprivation and work environment factors such as noise, vibration, and temperature.<br>• The most significant outcomes of fatigue include short-term cognitive and physical degradation and, to a lesser extent, error, injury, and illness.<br>• Most impacts of fatigue on physiology proved to be large. This was especially true for the effect of general fatigue among cognitive degradation and muscular fatigue among physical degradation. This is not surprising given the relatively large body of knowledge focused on this domain.<br>• The effect sizes of the relationship between fatigue and error or illness were moderate to low, but with weak significance. These results make sense, as errors and injuries are indirect results of acute fatigue and these effects can be caused by a plethora of external factors as well. |

| | |
|---|---|
| Lim, J., & Dinges, D. F. (2010).<br><br>*A meta-analysis of the impact of short-term sleep deprivation on cognitive variables.*<br><br>Psychological bulletin, 136(3), 375. | • A meta-analysis was conducted to discover the effects of short-term sleep deprivation on both speed and accuracy measures in 6 cognitive categories: simple attention, complex attention, working memory, processing speed, short-term memory, and reasoning.<br>• Seventy articles containing 147 cognitive tests were found that met inclusion criteria for this study.<br>• Across cognitive domains, significant differences were observed for both speed and accuracy; however, there were no differences between speed and accuracy measures within each cognitive domain.<br>• The results from this study support the conclusions of previous reviews that short-term total sleep deprivation has a significant deleterious effect across most cognitive domains. |
| Uehli, K., Mehta, A. J., Miedinger, D., Hug, K., Schindler, C., Holsboer-Trachsler, E., ... & Künzli, N. (2014).<br><br>*Sleep problems and work injuries: a systematic review and meta-analysis.*<br><br>Sleep medicine reviews, 18(1), 61-73. | • A systematic literature search using several databases was performed. Sleep problems of any duration or frequency as well as work injuries of any severity were of interest.<br>• The findings of the meta-analysis suggested that workers with sleep problems had a 1.62 times higher risk of being injured than workers without sleep problems.<br>• Approximately 13% of work injuries could be attributed to sleep problems. |
| Pires, G. N., Bezerra, A. G., Tufik, S., & Andersen, M. L. (2016).<br><br>*Effects of acute sleep deprivation on state anxiety levels: a systematic review and meta-analysis.*<br><br>Sleep Medicine, 24, 109-118. doi:https://doi.org/10.1016/j.sleep.2016.07.019 | • Systematic review encompassing two databases – Pubmed/Medline and Scopus – through which 756 articles identified. After the selection process, 18 articles, encompassing 34 experiments, composed the final sample.<br>• The analyses indicate that sleep deprivation, whether total or not, leads to a significant increase in state anxiety levels, but sleep restriction does not.<br>• Regarding the effect of the length of the period of sleep deprivation, no significant results were observed, but there was a notable tendency for an increase in anxiety in longer sleep deprivations. |
| A M Lock, D L Bonetti, A D K Campbell.<br><br>*The psychological and physiological health effects of fatigue.*<br><br>Occupational Medicine, Volume 68, Issue 8, November 2018, Pages 502–511, https://doi.org/10.1093/occmed/kqy109 | • Literature searches were conducted via scientific databases using appropriate filters and keywords. The available results were collated into a review and commentary.<br>• There is a large body of evidence showing strong associations between fatigue, reduced cognition and occupational accidents, as well as increased metabolic and reproductive health sequelae, some forms of cancer and mortality. |

| | |
|---|---|
| | • Additional evidence links fatigue with mental, gastrointestinal, neurological and chronic pain sequelae.<br>• Fatigue risk mitigation strategies should be implemented, not only to reduce these short- and long-term health risks in employees of safety-critical industries, but also to create more efficient, productive and effective workplace personnel with longer and more fulfilling careers. This requires improved acute fatigue mitigation, as well as the prevention of cumulative fatigue build-up and the formation of acute-on-chronic fatigue. The health recommendations for fatigue mitigation outlined in this paper are pertinent to all professions where employees have high rates of both acute and chronic fatigue. |
| J. A. Caldwell<br><br>*Fatigue in aviation.*<br><br>*Travel Medicine and Infectious Disease, 3*(2), 85-96, doi:https://doi.org/10.1016/j.tmaid.2004.07.008 | • Crewmember electroencephalographic activity has been monitored in several studies to determine the actual biological cost of long-haul and night operations. Episodes of increased slow-wave brain activity (often referred to as micro-sleeps or vigilance lapses) have been associated with generalized decrements on cognitive tasks as well as reduced speed of responding to incoming stimuli.<br>• Several in-flight evaluations have shown that micro-sleeps do in fact occur in cockpit crews.<br>• long-haul pilots are particularly susceptible to vigilance lapses during low-workload periods.<br>• pilot micro-sleeps tend to occur most frequently during the cruise portion of long haul operations (in the middle-to-late segments of the flight), and that micro-sleeps have been found to be more than 9 times as likely during nighttime flights compared to daytime flights.<br>• Such lapses go unnoticed by the affected crewmembers. Thus, a pilot may believe that he has successfully avoided the physiological realities of severe fatigue when actually, he has dozed off repeatedly. |

Quite clearly there is a wide range of studies reported above, each with different approaches and aims. Equally, the studies reported above have used different populations, and in different domains and used different research methods. However, the incidence of fatigue both in transport and other workplaces is generally in the region of 10-20% of all incidents. As noted above, as these domains are generally less controlled than in mining, it is unsurprising that fatigue-related incidents in mining are generally lower.

The above studies also frequently show the other negative safety and health impacts of fatigue and night-shiftwork. These include shiftworker digestive issues, cardiovascular problems, workplace cognitive failures and work-to-family conflict. Equally, anxiety is more prevalent and mental health is sometimes impacted by shiftwork-induced fatigue. A more detailed review of fatigue upon mental health and health and safety outcomes will be presented in Part 2 of this overall project.

# 4. Part 1C: Gap analysis

Based on the fatigue baseline outlined in sections 1A and 1B, a gap analysis is presented below to assess the likely effectiveness of current fatigue management processes from seven sites/companies. This section identifies gaps in the management of fatigue in the current procedures and systems implemented at the seven sites/companies. Note that a wider gap analysis of QGN16 against best practice fatigue management elsewhere will be presented in section 6.1.

***Background***. Queensland Guidance Note 16 was specifically developed to assist mine operators and mine workers to provide a comprehensive overview of the factors that contribute to workplace fatigue and how they can be controlled. This guidance replaced the existing fatigue management guidance note from 2001. Compared to the 2001 guidance note, which gave little assistance in identifying factors such as high risk roster design, fatigue risk factors, and suggested fatigue risk thresholds, QGN16 provides greater guidance (using a risk-based approach) to the fatigue-related issues relevant to mining. In addition, as was demonstrated in the earlier sections, there is a high degree of commonality between it and the guidance offered in NSW and WA. As such it is possible to include mines from NSW in the gap analysis. The guide was prepared to assist mine and quarry operators and workers in taking the necessary measures to control the risks associated with fatigue. Compliance with this guide is not required under the legislation, however it does offer advice that espouses to "*outlines the various considerations to effectively manage fatigue. It offers mine operators…. and mine workers….with a comprehensive overview of the factors that contribute to workplace fatigue and how they can be controlled.*" As such QGN 16 will be used a benchmark to compare the fatigue management processes provided by mine sites in order to identify any gaps in their processes.

Table 18 presents a comparison of the seven sites against QGN 16. Thereafter, Table 19 presents a summary of fatigue management as shown in a selection of corporate documents. Then, two summary case studies are presented: these focus on a couple of key aspects of fatigue management: the use of detection technologies and roster design.

Table 18 displays each of these factors individually in the first column and provides an assessment of the documentation provided by each of the 7 mine sites to determine whether they have covered the critical processes. Please note there are several factors that need consideration to fully understanding the table. First, the analysis presented is based only on those documents that the organisations volunteered and does not include an analysis of all documentation the organisations use to manage the risk of fatigue. Requests had been sent seeking additional documents that were identified in those provided however they were not available at the time of reporting.

Second, sites denoted by a "%" do not have sites located in Queensland therefore they are not obliged to meet the requirements of QGN16. Please note that site 5 refers largely to an organisation and includes documentation that was primarily corporate but also site-based. It also has mine sites in both Queensland and New South Wales. The remaining sites all referred to a specific mine site.

Overall assessment of the results is of interest. Not surprisingly, given the similarity between the guidance offered by the regulators, there is significant commonality across the sites. There were several factors that were consistently found across all sites irrespective of state the mine was operating. These were: recognition of fatigue as a hazard; hazard identification; risk assessment; risk control; and information, instruction, training and supervision.

There were several processes that were less clearly evident in the documentation. Queensland legislation requires workers to be consulted during the development of fitness for duty obligations. Overall, four directly referenced worker consultation. One site included an explicit quotation of the Coal Mining Safety and Health Regulation Part 6 Division1 Section 42 subsection 5 in its introduction which stated worker consultation is required however made no reference to this activity in its documentation. The other two only mentioned worker consultation as occurring after status of a worker's fitness for work had been questioned.

The hierarchy of controls was clearly referenced in only two sets of site documents. A further site, Site 4, contained a version of the hierarchy, however in the four remaining sites documentation the hierarchy appeared to be being applied but it was largely up to the reader to discern. Finally, for site 6 documentation embedded fatigue in a larger fitness for work process and references to identifying and use of resources was generic.

One interesting observation is that several company documentation state that the fatigued individual themselves is the best person to judge their fatigue level however research suggests that this may not be the case. Other organisations provide clear information on the sources of fatigue and controls for management suggesting further education and evaluation of controls may be beneficial.

**TAP for Coal Mines**

In February 2019 the NSW Resource Regulator published a Targeted Assessment Program (TAP) report on Fatigue management practices – NSW Coal Mines. Given the similarity between the NSW and Queensland fatigue guidance material, the gaps identified in the report may be relevant to the Queensland situation and may indicate the difference between what is in fatigue management plans and what is actually delivered on mine sites, although there be merit in undertaking a similar program in Queensland.

The NSW assessment program involved a multidisciplinary team of inspectors. The scope of the targeted assessment included two elements:

1. a desktop assessment of:
    - compliance against legislation with respect to managing risks to health and safety associated with worker fatigue
    - controls the mine uses to prevent and mitigate worker exposure to health and safety risks due to fatigue related impairment
    - means the mine utilises to monitor the effectiveness of those controls
2. a workplace assessment of the implementation of those controls.

The assessment process followed a bow-tie risk assessment as outlined in the figure 4 below.

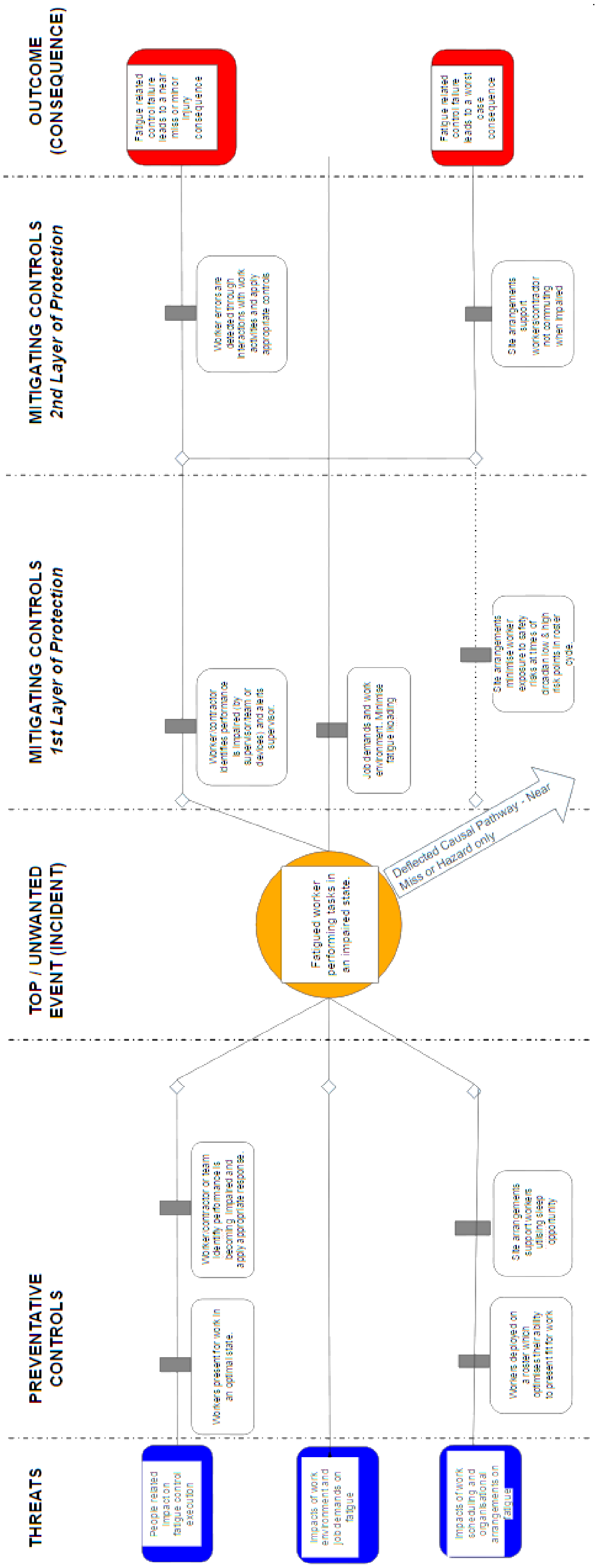



**Figure 4.** Bow-Tie Risk Assessment for 2019 NSW TAP

General findings highlighted issues with the risk assessment process for fatigue, such as:

- Workers at some mines not being provided with adequate information and training, with respect to fatigue effects and management, prior to participating in a risk assessment
- Supervisors not being trained on the implementation of fatigue management controls
- Fatigue risks were typically only considered as part of risk assessments associated with the development of rosters. Mine sites did not have a specific risk assessment related to the management of all risks associated with fatigue.
- Risk assessments did not include a person who was a content matter expert having regard to the nature of the hazard. Some mine operators did not adequately consult with workers or give them a reasonable opportunity to express their views and contribute to the decision-making process in relation to the risk assessment process.
- Mine operators had identified control measures in their management plan but had failed to consistently implement, monitor and/or review the control measures for fatigue.
- Mine operators had not reviewed the information, training and instructions on managing fatigue for supervisors.
- Workers did not always have an appropriate level of understanding of the operation of fatigue monitoring systems. Workers' views on the effectiveness and intent of technology-based systems that monitor an individual's physiological parameters varied depending on the amount of training provided.

The specific findings identified that:

- Supervisors were consistently working hours in excess of the limits defined in the fatigue management plan

- Control measures had been identified but not implemented consistently across all areas of the mine site for all workers
- Crib breaks were identified as a control but there were no systems in place to monitor and verify that crib breaks were being taken by workers
- Napping in cabins of mobile plant during second crib was common practice to manage fatigue in workers on night shift, yet the process was not identified in risk assessments nor documented in the fatigue management plan
- Journey management plans were not reviewed on a regular basis
- The mine operator had not implemented journey management plans for workers in accordance with the fatigue management plan.
- To date there has not been widespread implementation of this technology across the industry. Those operations that have implemented the technology, primarily on haul truck fleets, are much better able to accurately monitor the fatigue related events which are occurring and respond accordingly. The system, importantly, provides an engineering solution to continuous monitoring of operator fatigue, offering a higher order control that is consistent and autonomous.
- Mine operators did not have systems in place to monitor contractors' compliance with the fatigue management plan. Contractors were not always effectively monitored. Hours of work and roster patterns of itinerant contract workers were not considered in monitoring.

**TAP for Underground Metalliferous Mines**

In June 2020 the NSW Resource Regulator published a Final Consolidated Targeted Assessment Program (TAP) report on Managing Fatigue Risks in Underground Metalliferous Mines. The gaps identified in the report may be relevant to the Queensland situation and may indicate the difference between what is in fatigue management plans and what is delivered on mine sites. As with coal TAP the assessment program involved a multidisciplinary team of inspectors. The scope of the targeted assessment was identical to that of the coal TAP.

The findings from this TAP included:

*Risk assessments for fatigue were not conducted by a person who was familiar with the nature of the hazard in relation to the particular mine site.* While some operations had engaged experts in sleep science in the risk assessment that supports the FMP, other operations used onsite staff who were given no training in fatigue beyond PowerPoint slides in their induction. When determining hours of work as a control to manage worker fatigue, these hours of work need to be determined via the use of a recognised standard. Mine operators should consider engaging expert advice in the risk assessment and use this advice to determine the hours of work. In the absence of expert advice being available, mine operators should seek to determine worker hours via the use of a recognised bio-mathematical model

*The fatigue risks associated with a mine's roster arrangements had not been assessed against the control measures identified in the safety management system.* The roster arrangements also need to consider commuting times, call outs and overtime. Mine operators need to consider worker commuting times, not just going to and from work, but commuting times before and after their roster begins. Hours of work need to consider workers who are subject to call outs and who work overtime. Hours of work should be determined using a recognised bio-metric model and the mine should have a method of recording and enforcing hours of work. Any controls developed must be implemented for all workers at the mining operation – including contractors.

*Mine operators had not provided training to workers before they participated in the risk assessment for fatigue.* The mine operator must ensure that workers participating in a risk assessment are provided with adequate information, training and instruction to enable them to effectively participate in the development and implementation of strategies to protect workers at the mine from risks to health and safety arising from fatigue [clause 104(2)(e) WHS (MPS) Regulation].

*All mines identified the use supervisors to monitor worker fatigue as a control within their risk assessments and FMPs, however some supervisors reported they were unaware of this responsibility and had a limited understanding of how fatigue affects human health*. Mine operators must provide fatigue management training and instruction to all workers, including supervisors, in accordance with clause 104(2)(b) of the WHS (MPS) Regulation. All mine operators relied on supervision as a control in FMPs. Supervisor interaction with workers was identified as a key element in monitoring workers for fatigue. For supervisors to be effective in performing this monitoring function, effective training is essential

*Mine operators rely heavily on a workplace culture of self-reporting, to manage the risk of worker fatigue*. Every worker interviewed reported feeling comfortable self-reporting their fatigue and working with their supervisor to manage their fatigue with strategies such as having a coffee break, changing duties, having a power nap, all the way through to being driven home after their shift.

*As worker fatigue levels are affected by a multitude of factors, a whole-of-lifestyle approach is required.* It is recommended that not just workers, but worker families be given education in fatigue management and how to create the best home environment for workers to reduce their risk of becoming fatigued. It is also recommended that random fatigue assessments be conducted on workers, the same way random drug and alcohol tests are conducted.

*Mine operators identified control measures in their plans however failed to implement and/or review the control measures for fatigue consistently across the mine site.* The implementation, maintenance and review of fatigue-related control measures must be consistently applied across all areas of the mine site, including the preparation plants, workshop and maintenance areas, as per clause 37 WHS Regulations 2017.

*Mine operators did not have systems in place to monitor contractors' compliance with the FMP.* Contractors were not always effectively monitored. Hours of work and roster patterns of itinerant contract workers were not considered in monitoring. Operators must have systems in place to monitor compliance with the FMP for all workers on site, including contractors [clause 22 WHS (MPS) Regulation 2014].

*Some mines had inadequate processes to ensure the hours of work prescribed in the mine's FMP were being complied with by workers.* Mines should consider the use of higher order controls, rather than purely administrative controls to monitor hours worked. Mines should consider pre-programmed card swiping systems that monitor the time a worker spends on site and alarms when there is a breach (clause 36 WHS Regulation 2017).

*Some mine operators were adopting technologies to track worker alertness levels and using automated systems to determine worker fatigue levels.* Mine operators are required to manage the risk fatigue poses to workers as far as is reasonably practicable. Some mines have swipe access controls already at their operations, with workers swiping in and out, to record their time. It is recommended that mines with this facility upgrade it, so that an alarm is automatically triggered when people work for periods longer than what is stated in the operation's FMP.  As technological controls continue to improve in monitoring and manage worker fatigue, mine operators must remain informed of these technological updates and seek to implement these controls, as they become reasonably practicable (clause 36 WHS Regulation 2017).

*A mine operator had not implemented journey management plans for workers in accordance with the FMP.* Where journey management plans are identified as a control measure for workers (e.g. workers travelling more than one hour to and from the mine site), operators must ensure that plans are implemented and confirmed. Some workers were identified throughout the TAP who had not completed a journey management plan, despite this being company policy (clause 37 WHS Regulation 2017).

*There was a large amount of variability in how worker sleep issues were identified. Some* medicals included detailed questioning of a worker's sleep patterns and if necessary, workers were referred for sleep studies. Other medicals did not include specific questions around worker sleep patterns.

The individual nature of how fatigue affects a worker's health, means worker medicals can provide further insight into a worker's likelihood to suffer from fatigue. Worker health assessment should include questions around the worker's lifestyle and sleeping patterns identifies issues regarding the worker's sleep patterns, then the worker should be given training and advice on how to optimise their ability to rest when not at work.

There were areas of good practice identified:

Some mines identified fatigue as the single biggest risk to worker health and safety at their operation. This prompted the operations to engage medical experts in fatigue to participate in fatigue-related risk assessments and for mines to conduct a broad review around available controls for fatigue.

Some mines conduct annual medicals with specific questions around fatigue. They also conduct a medical three months after a worker has commenced at the operation to check how they have adjusted to working shift work. In these medicals, literature for the worker's immediate family is provided to optimise the worker's home environment to gain adequate rest.

Mine operators' use of fatigue monitoring devices was another area of good practice, where they wear a watch-like device that monitors a worker's alertness levels 24-hours a day. This allows workers to understand at what periods of the day their fatigue levels increase, how much sleep they are getting and gives feedback for aspects of their home and work environment that could be improved.

Two mines have budgeted to implement a real time monitoring system for truck drivers, where a series of scaled alerts are issued when a driver becomes fatigued. Such devices were found to be effective in the surface coal fatigue TAP program. The communication systems required to use such devices makes their implementation more difficult in the underground environment, however two mines have committed to their implementation. It is hoped that the results of their use in underground metalliferous mines is widely reported across industry.

Several mines have fatigue rooms available, where workers can go to sleep at any time. Similarly, for the management of fatigue when commuting between rosters, mines made rooms available for workers to sleep before starting their commute.

Notices were issued by assessment teams in response to the following identified compliance issues.

- People working more than 14 hours, in breach of the fatigue management plan.
- Workers had not submitted commute plans as required by the mine's FMP.
- Workers not complying with their journey management plans
- Supervisors not trained in the FMP and how fatigue affects human health.
- The implementation and review of control measures for minimising the risk that a worker will be exposed to fatigue were not consistently applied across the mine site.
- The mine operator has not engaged a competent person in the development of the risk assessment.
- The mine has not updated its risk assessment for fatigue when roster changes were made.
- Concerns around the level of worker training in how fatigue effects human health.
- Workers were not provided the results of fatigue monitoring devices.

The findings from these TAPs gives mines practical assistance in improving their fatigue management practices as well as providing the regulator with information on what areas require particular attention.  The use of TAP's or similar programs would be beneficial in assisting in the better management of fatigue in Queensland and should be considered by Resources Safety and Health Queensland.

## 4.1 Comparison of the likely effectiveness of company fatigue management processes

**Table 18.** Comparison of the 7 sites against QGN 16

| Fatigue Risk Management Processes from Queensland Guidance Note (QGN) 16 | Site 1 | Site 2% | Site 3% | Site 4% | Site 5%% | Site 6% | Site 7 |
|---|---|---|---|---|---|---|---|
| **Recognition of Fatigue as a hazard**<br>*"There is a direct link between fatigue and increased risk of being involved in an incident or accident."* | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| **Organisational Obligations to manage fatigue**<br>*"Operators and SSEs hold the fundamental obligation for managing the risks associated with fatigue."* | ✓ | ✓ | ✓ | ✓ | ✓ | ∞ | ✓ |
| **Individual Obligations to manage fatigue**<br>*"All workers on-site, including contractors and other on-site service providers, must be involved in implementing the fatigue risk management plan and in making sure it is followed."* | ✓ | ✓ | ✓ | ✓ | ✓ | ∞ | ✓ |
| **Worker Consultation**<br>*"Consultation must be undertaken as required by legislation."* | ~ | ~ | Only stated as CMSHR (2017) 42(5) | ✓ | ✓ | ✓ | ✓ |
| **Roles and Responsibilities**<br>**Advised:** *"The roles and responsibilities of persons within the organisation who will have responsibility for developing and implementing the plan should be identified."* | ✓ | ✓ | ✓ | ✓ | ✓ | ∞ | ✓ |
| **Resources**<br>*"Those responsible for the development and implementation of the fatigue risk management plan must ensure that appropriate resources are made available as per their legislative requirements under Queensland legislation* | ✓ | ✓ | ✓ | ✓ | ✓ | Not specifically mentioned | ✓ |
| **Hazard Identification**<br>*As part of the four-step risk management process as required under the CMSH regulation* | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| **Risk Assessment**<br>*As part of the four-step risk management process as required under the CMSH regulation* | ✓ | ✓ # | ✓ | ✓ | ✓ | ✓ | ✓ |
| **Risk Control**<br>*As part of the four-step risk management process as required under the CMSH regulation* | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| **Hierarchy of Controls**<br>*Elimination, Substitution, Isolation, Engineering controls, Administrative controls, PPE* | ✓* | ✓* | ✓ Clearly stated | ✓ | ✓* | ✓ Clearly stated | ✓* |
| **Information, Instruction, Training and Supervision**<br>*"All site personnel, including contractors, must be informed about the fatigue risk management plan and have the skills and knowledge they need to fulfil their roles and responsibilities. Coal mine sites have obligations for an education program under the CMSH Regulation, s.42 (2). Legislation requires proper supervision of workers (including contractors) and appropriate supervision is an essential part of the fatigue risk management plan.* | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| **Evaluation of Controls**<br>*As part of the four-step risk management process as required under the CMSH regulation* | Not specifically mentioned | ✓ | Not specifically mentioned | ✓ | ✓ Clearly stated | ✓ | ✓ |

% - Site not in Queensland; %% - Sites in Queensland and New South Wales

~ Only mention consultation as occurring after fitness for work has been questioned (e.g., a decision is necessary whether to remove someone from the workplace).

∞ Document embed fatigue management in Fitness for Work. Reference is generic stating organisations and individuals have obligations to monitor hazards.

# RA was implied but not specifically included.

* HOC was specifically mentioned by 2 sites only. It appeared to be applied at the remaining sites however it was largely up to reader to discern.

## 4.2 Fatigue management in mining corporate documents

**Mining Companies – website research**

Part of the project involved determining what information mining and minerals organisations made publicly available regarding their management of fatigue. It should be noted that the scope of this review does not examine what is available to the workforce through the internal internet sites. A search was conducted to identify the organisations in Australia that undertook mining, primarily in Queensland and New South Wales as these were the states that the organisations volunteered their fatigue management documentation. The search was limited to their Australian websites where available and any documentation they referred to, where publicly available, on those sites. Table 18 presents the findings for eleven companies.

Overall, fatigue was rarely if ever mentioned in the Annual Report for 2022. Only 3 of the 11 companies made any reference to fatigue management. Where a Strategic Report was available only 2 mentioned fatigue. Sustainability Reports, where available and mentioned fatigue, tended to provide a focus piece on fatigue management. For example, one included information on a project involving the purchasing of self-testing equipment for personnel to determine if they had sleep apnoea. The search also included any other documentation organisations published, however only one organisation published extensive educational material on fatigue.

A search was conducted on each of the organisations home pages for fatigue through the search function at the top of the page. Over half of the searches for fatigue, and related terms, yielded ‘zero’ results. The child pages of each organisations home page were also searched for fatigue information. Of the 11 organisations, only 5 referenced fatigue. Across the remaining 6 organisations fatigue was not mentioned and this included searches of their “Safety and Health, or Sustainability” child pages where they had them. Most organisations did not reference any procedures or processes they used to manage fatigue. Of the four that did have references, these were to Fatigue Management Standards or Plans / Strategies.

Websites were also searched for their use of technology to manage fatigue. Only 5 mentioned the use of technology to either diagnose sleep disorders or monitor operator performance for the impact of fatigue. These included real-time / behaviour monitoring, SmartCap system, Sleep apnoea equipment, FAID, wearable tech and Readiband. One company also mentioned the introduction of automation to reduce fatigue. Any additional information that organisations mentioned that directly targeted fatigue was captured. One company mentioned 2 initiatives in particular. The first in Ecuador (3000mASL), where fatigue and drowsiness was identified as a leading contributor to accidents. They engaged an external provider to undertake sleep assessments and identified sleep disorders. They then introduced SmartCap tech. The second, in WA Iron Ore where they targeted changes to the roster and reduced fatigue related events among haul truck drivers by 60%. One company also constructed a new airport which reduced travel time and thus helped manage fatigue.

In summary, mining organisations do not appear to extensively publicise information on their websites about fatigue, its impact on their business or how they manage it in any great detail. The use of the term fatigue across websites was quite broad. When mentioned, it ranged from generic statements about health and safety, to specific initiatives to reduce fatigues impact on workplace incidents. Furthermore, where the term fatigue was used in websites also varied. Sometimes it was found where the user would not expect such as under the child page of 'Health and Safety', and other times searches were required outside where it was expected. For example, the only reference to one company Fatigue Audit was located as reference information in their modern slavery document. Very few organisations had a dedicated section on their website to fatigue. Organisations also reported a range of ways they were addressing fatigue. This included roster design, reducing commute times and technology. However, it was clear that organisations don't necessarily report all their initiatives. For example, on their website a company report no use of technology or software however elsewhere they actively use and discuss their use of Guardvant technology to manage fatigue. In general, larger organisations tended to comment on fatigue more frequently than the smaller organisations. No organisations made publicly available their Fatigue Management Standard or Plan / Strategy, nor their Journey Management Plan or Rostering Standards. However, one organisation at least was making educational material about fatigue, its effects and management publicly accessible. This research analysed the results of a limited number of mining organisations therefore the results may not be representative of the wider mining and resources industry. Different and larger amounts of information may have been found if other global websites were included in the research. There was also the potential of including a larger number of mining and minerals organisations to the research.  Some caution therefore is warranted when considering the applicability and transferability of these results to other mining or resource industries.

**Table 19.** Summary of fatigue management in corporate documents

| Company (de-identified) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Website review date | 11/08/2022 | 1/07/2022 | 28/06/2022 | 28/06/2022 | 30/06/2022 | 11/08/2022 | 28/06/2022 | 28/06/2022 | 28-30/06/22 | 11/08/2022 | 11/08/2022 |
| Annual Report | Fatigue=3<br>Three mines identified. Each mentioned fatigue.<br>Technology mentioned at 2 mines: 1-first phase of real-time monitoring of speed and driver fatigue status, & 2-behaviour monitoring to manage haul truck driver speed and capability (unclear if same tech) | Fatigue was not mentioned | No report found | Fatigue was not mentioned | Fatigue was not mentioned | No report found | Fatigue=1.<br>Identified as a Health and Safety risk. | Fatigue=5<br>Fatigue as a risk to safety, investment in personal monitoring tech, increased workload, and leadership team focusing on fatigue management. | Fatigue was not mentioned | Fatigue was not mentioned | Fatigue was not mentioned |
| Strategic Report | No report found | No report found | No report found | Fatigue was not mentioned | No report found | Fatigue=1<br>Fatigue Management was reviewed and updated. | No report found | Fatigue=4<br>Fatigue as a risk to safety, investment in personal monitoring tech, and increased workload. | No report found | No report found | No report found |
| Sustainability Report | Fatigue=1<br>'Fatigue management' - no elaboration | No report found | No report found | Fatigue=9.<br>Dedicated section on fatigue management. Initiatives included:<br>WA - Sleep Apnoea equipment purchased to enable self-testing for both employees and contractors.<br>FM tools to support workforce planning (inc FAID).<br>SmartCap use extended - 198 units in operation 2021<br>Enhanced reporting tools to capture extra hours across sites. | Fatigue was not mentioned | No report found | Fatigue=12<br>Fatigue identified as a long term priority and a risk to incident.<br>Dedicated section on fatigue - a key focus of health and hygiene programs. | No report found | Fatigue was not mentioned | Fatigue=2.<br>Specific section in 'Health and Safety Initiatives' - Financial support given to employees, through local housing allowance policy, that demonstrates compliance with FM requirements & Journey Management Plans. | No report found |
| Other documents | | Tip Sheets (short education documents) 2 dedicated to fatigue and sleep.<br>Mental Health Month (educational document) 2 dedicated to fatigue (inc fatigue as a psychosocial hazard) | | | | | | | ASX Information Memorandum - Fatigue=3. Generic reference. | Safety and Health Policy Statement does not mention fatigue | |
| Australian website - Search function at top of page - Parent/Heading tab level | Fatigue=3<br>Fatigue management monitoring - The SmartCap.<br>Road Safety Week.<br>Fatigue assigned mandatory technical standard. | Fatigue=24<br>References were broad (Mental Health Month, initiatives that have reduced fatigue, educational power points, fatigue as a contributor to incidents, etc). | Fatigue was not mentioned. Health and Safety Policy does not mention fatigue. | Fatigue was not mentioned | Fatigue was not mentioned. | Fatigue was not mentioned | Fatigue was not mentioned | Fatigue=2<br>New airport to help manage employee fatigue by reduced travel time, leadership and fatigue, and fatigue management. | Fatigue=6<br>Articles that made generic mention of fatigue. Only 1 had dedicated section ( Readiband) | Fatigue=0 | Fatigue was not mentioned |

| Company | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Website review date | 11/08/2022 | 1/07/2022 | 28/06/2022 | 28/06/2022 | 30/06/2022 | 11/08/2022 | 28/06/2022 | 28/06/2022 | 28-30/06/22 | 11/08/2022 | 11/08/2022 |
| Child sites - tabs and sub-tabs | Fatigue=1<br>'Safety and Health' subtab (under Sustainability tab) | Fatigue=4<br>Sustainability tab - Subtab Safety and Health.<br><br>References included - fatigue management, FM Strategy, Review of fatigue control mechanism and developed minimum requirements. | Safety tab does not mention fatigue. | Fatigue=1<br>'Our Culture' sub-tab.<br>Mentioned once in "Employee code of conduct and integrity policy" | Fatigue=0<br>No sub-tabs mention fatigue.<br>Fatigue is not mentioned 'Sustainability', 'Health' or 'Safety'. | Fatigue=0<br>No sub-tabs mention fatigue.<br>'Safety and Health' and 'People' subtabs do not mention fatigue. | Fatigue=0<br>No mention of fatigue in: Safety and Health Policy, Sustainability Policy, or Risk Management Policy. | Fatigue=2<br>Sustainability tab: Sub-tab 1. Health, Safety and Wellbeing. No dedicated section to fatigue.<br>Fatigue seen as a 'critical risk'<br>Mentions wearable tech but not named<br><br>Fatigue=0<br>Sustainability tab: Sub-tab 2. Policies and Standards. Of the 120 documents listed only 2 mentioned fatigue once. | Fatigue=2<br>Health sub-tab made generic reference to fatigue management. | Fatigue=0<br>No sub-tabs mention fatigue.<br>Health and Safety sub-tab do not mention fatigue. | No Health and Safety tab |
| Any fatigue documents mentioned on website that are not publicly available | Fatigue has an assigned mandatory technical standard. Includes requirement for RA, education and training, application of controls, and monitoring and review. | Fatigue Management Standard<br>Fatigue Management Strategy<br>Fatigue Management Plan<br>Journey Management Procedures<br>Fatigue self-assessment tool | No FM documents mentioned | No FM documents mentioned | No FM documents mentioned | Fatigue Management Plan | Fatigue Management Standard - sets minimum expectations, roster changes, deep-dive review, etc | Fitness for Work Standard | THRIVE Mental Health Program though EAP.<br>Fatigue Management Plan.<br>Fatigue Audit. | Journey Management Plan | No FM documents mentioned |
| Technology / software mentioned | 1. Real-time monitoring of speed and driver fatigue status.<br>2. Behaviour monitoring to manage haul truck driver speed and capability.<br>(unclear if same tech)<br>3. The SmartCap | 1. Ecuador - automation initiative reduced material risk (crushing / entrapment) and reduced fatigue.<br>2. Smartcaps | | 1. Sleep Apnoea equipment purchased to enable self-testing for both employees and contractors.<br>2. FM tools to support workforce planning (inc FAID).<br>3. SmartCap use extended - 198 units in operation 2021.<br>4. Enhanced reporting tools to capture extra hours across sites. | | | | 1. Wearable tech is mentioned but not named | 1. Tech trial - manage fatigue risk, reduce fatigue related safety incidents, and improve wellbeing - Readiband™ writs activity monitored and sent to Safety Alertness Fatigue Task Effectiveness (SAFTE) model in an app. | | |
| Additional information | | 1 Saraji East mining lease - Dedicated section on FM.<br>2. Ecuador - 3000mASL, fatigue and drowsiness leading contributor to accidents. External provider sleep assessments identified sleep disorders and introduced SmartCap tech.<br>3. WA Iron Ore - fatigue reduced through roster change resulting in 60% reduction in fatigue related events among haul truck drivers. | | | | | | 1. Construction of new airport to help manage employee fatigue by reduced travel time, leadership and fatigue, and fatigue management. | | | |

## 4.3 Fatigue management summary case studies

Two summary case studies are presented: these focus on a couple of key aspects of fatigue management: the use of detection technologies and roster design.

### 4.3.1 Case study 1: BHP Mount Whaleback, WA

**Better sleep, safer mine: Fatigue reduction through roster change (2019). Sean O'Hanlon, Western Australia Iron Ore, Minerals Australia**

(from https://www.bhp.com/news/articles/2019/02/2019-health-safety-environment-and-community-awards )

Mining employees at Western Australia Iron Ore's (WAIO) Mount Whaleback operations have worked a two-day, two-night, four-day off roster for the past 20 years. But the roster's short duration and the rapid change from day to night shift had become a potential fatigue concern for the workforce. The Whaleback team took a holistic and comprehensive approach to review rosters across the operation, and identify a solution.

Strong leadership and an extensive employee engagement plan was central to the successful roll out of the new, even time 'Lifestyle Roster'. The team also engaged our Employee Assistance Program to provide employee and community fatigue workshops, and a Better Sleep Program. Functional teams stepped up to help prepare employees for the change, including putting housing and flexible work arrangements in place where needed.

Since the Lifestyle Roster has been in place, Mount Whaleback has achieved a 60 per cent reduction in fatigue related events among haul truck operators, and for the first time we have been able to directly measure the safety outcomes of a roster change. Not only has the team achieved a material risk reduction, they have also made a broader impact on employee and community health and wellbeing, and improved the operation's productivity. The approach now provides a proven methodology to consider for potential future workforce changes across BHP, and will contribute to industry fatigue research.

### 4.3.2 Case study 2: Operator Awareness System at Glencore Coal Assets Australia:

**Interviews with Neil Pollard, Glencore (2022)**

Operator fatigue and distraction are long-standing safety issues in mining. Over the past twenty years, fatigue detection technologies have become more reliable and usable and can now form a valuable part of an organisation's fatigue management system.

This case study describes an industry-leading approach by the company Glencore Coal Assets Australia (Glencore) to deploy an operator awareness system (OAS). Through careful analysis and preparation, worker consultation, system selection, staged adoption, Trigger Action Response Plans (TARPs), ongoing safety evaluations, and post-implementation management the Glencore's OAS has been successfully deployed across their surface coal mines in Australia. However, it should be noted that although Glencore coal mines NSW and Queensland use the Operator Alertness System, in Queensland Glencore's mines do not use the associated Health TARP and Fitness for Work Assessments due to Section 42 requirements of the CMSH Regulations

Overall, using the OAS, Glencore have seen a year-on-year reduction in fatigue for mobile equipment operators - both in frequency (overall count) and severity. Perhaps the most important finding is that only one recordable fatigue-related incident has occurred across all Glencore Coal Assets sites in Australia since the OAS was fully deployed in 2019.

## 4.4 Section conclusions: Industry gaps in fatigue management

The companies who provided information, demonstrated that they include the majority of QGN16 contents in their fatigue risk management systems.  It is difficult to assess the level of detail applied from the supplied documentation as in most cases there are subsidiary documents and processes that are applied, which were not supplied.  One corporate office did supply a suite of supporting documents and a high-quality detailed bowtie analysis for fatigue management.

Areas for further consideration are:

- Processes to monitor the potential longer term health effects from fatigue. This is not surprising as adverse safety outcomes are incident based and may be identified relatively easily.  Tracking decrements in health over time and ascribing them to fatigue is inherently more difficult.  Health impacts in general are only described at a high level.  In addition, a further complication is the influence of non-work factors on worker health.
- Mental health outcomes. As with other health outcomes identifying the contribution of fatigue to poor mental health and then to adverse health or safety outcomes is inherently difficult.  The guidance material offers very limited information and advice.  This will be discussed further below.
- Technologies. There have been attempts to implement technology to predict and prevent fatigue for more than twenty years. Unfortunately, early technology was not based upon rigorous science (eg OSPAT or FIT2000) or was too simplistic (early computer models, fatigue calculators, etc). The most successful technology appears to be in managing the fatigue levels in mobile plant operators and preventing accidents. Additionally, the technology shown above in the Glencore case study did have a positive impact when combined with other organisational measures and processes (eg the health TARP).
- Fatigue management corporate leadership. Mining companies have significantly improved their fatigue management processes over the past decade. However, further ‘top-down’ emphasis about the importance of fatigue management may add extra visibility to the issue. Such corporate level initiatives would help to keep fatigue management as a prominent area.

The level of training and information provided to workers and supervisors varied greatly between sites, including the level of understanding of how fatigue monitoring systems worked.  The 2019 NSW TAPs found that the risk assessment process at a number of sites needed improvement including:

- Use of a content matter expert
- Broadening the scope of the risk assessment to include management of all risks associated with fatigue.
- Consistent implementation, monitoring and/or review of controls
- Management of contractor compliance with fatigue management plans

The next section will consider in depth one of these areas: mental health. It will present a review of fatigue and mental health in mining and its links to safety.

# 5. Part 2: Literature review on relationships between fatigue, health and safety, and mental health within the mining industry

Understanding relationships between fatigue, health and safety, and mental health within the mining industry are essential to ensure proper and effective risk management. To further this understanding a systematic review was conducted to synthesise extant literature in relation to three core questions:

1. What is the relationship between fatigue and health and safety outcomes in the mining industry?
2. What is the relationship between fatigue and worker mental health in the mining industry?
3. Does worker mental health predict fatigue-related safety outcomes in the mining industry?

This review is structured around these three research questions and for this review terms are defined as below:

**Health and safety outcomes**: work-related illnesses, occupational injuries or fatalities, workplace rehabilitation outcomes, lost work time, return to work, absenteeism, and vehicle incidents.

**Mental (ill) health**: conditions where there are disturbances in an individual's cognition, emotional regulation, or behaviour including, but not limited to, anxiety, depression, stress, burnout, isolation, psychological distress, and work-life conflict.

**Mining industry:** For the purposes of this review, organisations in the mining industry are defined as those that mainly extract: naturally occurring mineral solids (i.e., coal and ores); liquid minerals, such as crude petroleum; and gases, such as natural gas. This includes: underground or open cut mining; well operations or evaporation pans; recovery from ore dumps or tailings; beneficiation activities (i.e. preparing, including crushing, screening, washing and flotation) and other preparation work customarily performed at the site. Both mine operation and mining support activities are included. (Definition adapted from the Australian Bureau of Statistics definition of “extractive industries”; ABS, 2013)

**Worker fatigue:** the decreased capability to perform mental or physical work, produced as a function of inadequate sleep (quantity or quality), circadian disruption or time on task (Brown, 1994).

In conducting this review, a systematic search of the literature was conducted using structured search terms and inclusion/exclusion criteria. Four databases were searched to find eligible papers: PubMed, Web of Science, Elsevier via Embase and CINAHL. 3449 studies were retrieved at this stage. In addition, grey literature and industry reports were sourced.

Moving to the selection phase, duplicate searches were removed using the software programs Endnote and Covidence. This left 2,914 articles which were screened, via title and abstract, by three research team members using Covidence. Once articles that did not meet the inclusion criteria were removed, independent full-text screening of 462 articles was conducted by two research team members. Through the process, any article discrepancies were resolved by the research team. Finally, a total of 88 articles related to fatigue, health and safety, and mental health within the mining industry were summarised for this review.

## 5.1 Research question 1: What is the relationship between fatigue and health and safety outcomes in the mining industry?

Workers within the mining industry experience a greater prevalence of work-related accidents, mortality, and adverse health and safety outcomes than those in many other industries (SafeWork Australia, 2021). The literature surrounding worker fatigue and health and safety outcomes within the mining industry suggests that work characteristics (such as shift work and work scheduling, environmental conditions, and high requirements for driving tasks) can lead to circadian disturbances, chronic sleep loss, sleep disturbances, and poor sleep quality which are significant predictors of both health and safety outcomes (Asare et al., 2021; de Arruda & Gontijo, 2012; Djamalus et al., 2021; Gao et al., 2019, Dugdale et al., 2022). In addition, workers that experience fatigue are more likely to be susceptible to fatigue-related work risks and cognitive impairments, which can also lead to severe injuries or fatalities (Bauerle et al., 2021). Some of these factors are common across other industrial domains, whilst others are specific to the mining industry. The following sections will discuss literature related to each of these work characteristics and how they may influence this relationship. In addition, studies related to individual differences and fatigue related health and safety outcomes are synthesised.

### 5.1.1 Shift Work and Work Scheduling

Extensive research has been conducted on the effects of irregular working hours associated with shift work within the mining industry and its impact on fatigue and health and safety outcomes (Fossum et al., 2013; Ross, 2009). A review by Folkard (2005), discussed the shift work characteristics and the risk of work-related accidents or injuries in workers across all industries. Findings concluded, that although the risk may not always be caused by sleepiness levels, shift systems within the industry should still consider a design that minimises these shiftwork related risks (i.e., risk associated with night-shifts, increased risk over a span of shifts and shift lengths over 8 hours). The effects of shift work often lead to lowered alertness and performance in work due to the disruption of the sleep-wake cycle (Fido & Ghali, 2008). Besides its direct implications on work-related health and safety, extensive periods of shift work may result in chronic sleep loss, shortened sleep, daytime fatigue and cumulative fatigue effects with long-term repercussions on shift workers' health (e.g., high blood pressure, high cholesterol, obesity) (Parkes, 2012; Ryan et al., 2017) and greater susceptibility to accidents (Fossum et al., 2013). A study by Muller et al. (2008), also demonstrates that diurnal rhythm and night shifts of more than eight days might be a primary contributing factor to occupational fatigue as workers show significantly elevated fatigue ratings and slower response times at the end of their shifts, compared to the beginning of their shift.

#### *Health Implications of Shift Work*

The prevalence of sleep disorders is relatively high among shift workers in the mining industry, with evidence reporting its direct influence on worker fatigue and health and safety outcomes (Bhattacherjee et al., 2007). Individuals with sleep disorders reported poorer sleep quality and more subjective health complaints such as excessive sleepiness or insomnia (Waage et al., 2009). Due to the nature of work in the mining industry, shift workers are often at a greater risk of experiencing sleep disorders due to irregular working hours and work-related stress (Ning et al., 2020). Obstructive sleep apnea (OSA) is a common sleep disorder among shift workers in the mining industry. Workers classified as overweight are more susceptible to developing OSA. Factors such as increasing the number of shifts worked, age, marital status, and length of service were also reported to increase the risk of developing a sleep disorder for mine workers (Zhou et al., 2022). Regarding the length of service, workers with shift work experience of fewer than 5-years and more than 15-years had greater susceptibility to developing a sleep disorder compared to those workers in-between (Cui et al., 2015). Speculatively, this may be the result of a combination of age and exposure effects for the older workers, and worker attrition (i.e., younger workers who have a greater susceptibility to sleep disorders may be less likely to stay in the industry long enough to be in the 5- to 15-year experience bracket). Consistent with these findings, Langdon et al. (2016) found similar evidence of individual risks and health issues associated with sleep disruption and accumulated fatigue due to work hours.

Several studies have described relationships between shift work / hours of work in mining and adverse health outcomes such as an increased risk of cardiovascular and gastrointestinal disorders (Duchon & Keran, 1990). Varying characteristics such as irregular eating habits, irregular eating patterns, and poor nutritional hygiene were common factors associated with shift work. However, other studies have failed to find adverse health outcomes in workers who work longer shift schedules (Hanoa et al., 2011).

Several studies have also recognised the prevalence of obesity among shift workers within the mining industry. First, it is suggested that shift workers' accumulated wakefulness and sleep deprivation may impair glucose and fat metabolism (Marot et al., 2021). Ingesting food after long periods of sleep deprivation also harms metabolic health, increasing the risk of obesity, Type II diabetes, heart and kidney disease, stroke, and non-alcoholic fatty liver disease**.** Studies also report that higher stress levels experienced by shift workers may lead to unhealthy eating behaviours, such as a higher intake of food with high calories and less intake of low caloric foods (e.g., fruits and vegetables) (Asare et al., 2022). Other unhealthy behaviours, such as higher levels of alcohol consumption and smoking within the population of shift workers, may also pose a likely contributor to obesity and other adverse health outcomes (Asare et al., 2021; Yeoman et al., 2020).

Other health implications, such as impaired cognitive function, have also been associated with shift work. Studies show that workers who work night shifts are more susceptible to cognitive decline and impairment over their lifespan compared to those who work day shifts (Zhao et al., 2021). As sleep is required for memory consolidation and normal brain function, sleep disturbance associated with shift work may interfere with the function of neuronal pathways, which can impair synaptic plasticity. As a result, evidence demonstrates a significant relationship between shift work and impaired or declined cognitive function over the lifespan.

Leisure time activities have also shown to be beneficial for recovery from work-related fatigue, serving as a process that is important for the worker's health maintenance (Merkus et al., 2017).  Interestingly, another study that focused on better understanding the effects of leisure time on fatigue in workers found that this leisure time may not reduce fatigue in workers (Ferguson et al., 2010). Instead, work-related factors such as shift start times and day length were critical mediators of sleep quality and fatigue.

Overall findings suggest that higher stress levels, shorter sleep duration, poorer sleep quality and sleep disturbances associated with the nature of shift work likely increase the likelihood of adverse health outcomes.

*Safety Implications of Shift Work*

Numerous studies have also focused their attention on worker fatigue and safety outcomes in mining shift work and found a correspondence between shift work and the risk of work-related accidents and mortality (de Arruda & Gontijo, 2012). Shift work characteristics, such as prolonged working hours, irregular sleep patterns and misaligned circadian rhythm, were associated with compromised attention levels (Rosa et al., 2019). Reduced attention and concentration levels in workers often lead to an increase in severe injury risk (Chimamise et al., 2013). Additionally, it was found that high mental fatigue caused cognitive, emotional, and motor deterioration, affecting the work performance of workers  (Djamalus et al., 2021).

A number of studies found that work-related fatigue may compromise workers' safety in the mining industry, such as increased risk-taking behaviour (Chen et al., 2019; Jia et al., 2022). Additional factors such as inexperience and poor fitness for duty may also act in combination with mental fatigue to predict unsafe behaviours including skill-based errors, decision errors, perceptual errors, and violations (Chen et al., 2019).

Finally, Nielsen et al. (2016) conducted a study to identify the direct and indirect associations between shift work, sleep problems, health complaints and psychological safety climate (measured using the used the 11-item Brief Norwegian Safety Climate Inventory (Brief NORSCI). The results imply that sleep problems may mediate between shift work schedules and safety climate, which suggests that to improve safety within the industry, work routines should focus their design on promoting sleep and rest among shift workers (Nielsen et al., 2016).

*Studies exploring patterns of work scheduling*

Several studies have focused on the health and safety implications of swing shifts (defined as shifts that start later in the day and extend into the night) compared to the regular day-night shifts in the mining industry. First, Bjorvatn et al. (2006) explored the effects of shift workers' (re)adaptation from day to night shifts on fatigue. Findings suggest that when rotating between shifts, workers' sleepiness and quality and quantity worsened, reporting a pronounced level of fatigue. However, this (re)adaptation between shifts has shown to be more difficult in swing shifts compared to regular day-night shifts (Saksvik et al., 2011) and more difficult in night-shift workers compared to day-shift workers (Fossum et al., 2013). Workers who experience fatigue from the re-adaption in swing shifts have also reported greater levels of sleepiness and lower alertness on the day of shift rotation (Bhuanantanondh et al., 2021). Consistent with these findings, Harris et al.'s (2010) study on workers' health, reaction time and cortisol rhythm on swing shift rotations found that cortisol rhythm was relatively flat on the day of the rotation which might indicate a disruption of the worker's circadian rhythm (Harris et al., 2010). In summary, swing shifts influence factors such as sleep quality, alertness and circadian rhythm disruption, which can lead to increased fatigue levels in workers.

Several studies have explored and compared the effects of regular and extended workday shifts on workers' fatigue and health outcomes. Typically, a regular workday shift is considered 8 hours, while an extended workday is between 10–12 hours while maintaining a 40-hour work week. In addressing possible adverse health and safety outcomes of such schedules, Friedman et al. (2019) found that after the adaptation of the 10- to 12-hour shift from a regular 8-hours shift, the number of injuries multiplied three-fold, with injuries mainly occurring 9+ hours into the shift. However, other studies that compare workers' psychomotor and physiological performance in mining environments found differing findings (Baker et al., 2001; Duchon et al., 1994). These studies indicated no change in workers psychomotor or physiological performance pre-, mid- and post-shift, between a regular 8-hour to a 12-hour schedule. Duchon et al. (1997) further explain, when monitoring the heart rate of workers, that the extended workday schedule does not lead to pronounced fatigue effects, possibly due to the pacing of work effort on a 12-hour shift compared to the 8-hour shift.

In contrast, recent studies evaluating the long-term effects of extended workday scheduling indicate that 12-hour shifts may lead to fatigue-related adverse health outcomes (Asare et al., 2021) and increased safety risks from chronically restricted sleep (Paech et al., 2010). Consistent with these findings, extended workdays also led to a significantly higher subjective post-shift rating of workers’ fatigue which has been shown to affect workers' sleep quality and insomnia during shifts (Baulk et al., 2009; Waage et al., 2013).

Despite these inconsistent findings on the effects of extended workday shifts, Baulk et al. (2009) suggest that shift schedules should be optimised to allow workers to attain adequate rest and recovery between shifts in order to lower the risks of potential adverse health outcomes. Nonetheless, more stringent data collection methods may be required to record factors like overtime hours of work to inform future risk management strategies (Cliff, 2005).

### 5.1.2 Environmental Conditions and Work Characteristics

Several studies have shown that environmental conditions, such as high ambient temperatures (Legault et al., 2017), noise exposure (Li et al., 2021), or work characteristics such as high job demands may contribute to the effects of worker fatigue and lead to a higher risk of adverse health and safety outcomes. For example, one study found that workers in the offshore extractive industries who perceived they had high job demands reported greater mental and physical fatigue (Hystad et al., 2013).

Miners who work in hot and humid environments experience higher levels of thermal strain, greater fatigue levels, more disrupted sleep, and subsequent cognitive dysfunction during work times (Legault et al., 2017). Cognitive impairment or dysfunction may develop from the combined effect of heat exposure, mining workplace activities that may increase heat gain, and poor opportunities to dissipate the heat through diaphoretic processes (i.e., sweating) (Legault, 2011). These combined causes are reported to worsen the effects of cognitive impairment over the duration of the shift. In addition, experiencing heat stress or exhaustion is a major concern for the health of miners working under high ambient temperatures (Nunfam et al., 2021). Pre-developed fatigue, from  poor sleep quality, insufficient recovery and alcohol consumption in workers was revealed to increase the susceptibility to heat stress illnesses or exhaustion (Roy et al., 2022). To support these overarching findings, Ogiński et al. (2000) also revealed that accidents and injuries occurred more frequently during the summer compared to winter, suggesting that exposure to heat may indeed influence the likelihood of adverse health and safety outcomes (Ogiński et al., 2000).

Mine workers are commonly faced with either short- or long-term noise exposure, which may lead to an increased risk of work-related accidents from lowered attention, decreased reaction time, and visual fatigue (Li et al., 2021).

### 5.1.3 Individual factors

Individual factors such as age, gender, individual health, and social factors may also be variables that moderate the relationship between fatigue and health and safety outcomes. First, evidence suggests an association between age and health outcomes, such that older workers are more susceptible to poor sleep quality and duration (Parkes, 2016). Factors such as low control over work activities (Loudoun et al., 2014) and working overtime (Parkes, 2015) were also associated with more significant sleep disturbances in older workers than in younger workers. However, compared to the younger population of shift workers, older workers may have improved tolerance to shift work, less domestic demands, enhanced coping skills and reduced sleep needs, which may lower their risk of experiencing adverse health outcomes (Waage et al., 2010).

Regarding effects of work-related fatigue on safety outcomes, Jafari et al. (2018) investigated the individual characteristics of workers. They found that factors such as consumption of sedative pills and presence of sleep disorders contributed to work-related accidents in the industry. The ability to return to work after sustaining work-related injuries was also found to be influenced by fatigue-related individual factors. A study by Bhattacherjee and Kunar (2016) investigated factors affecting miners' return to work from injury and found that longer sleep time each night, among other things (fewer dependants, the absence of job stress, disease and alcohol addiction, injury type and higher income) had a significant impact on a worker's return to work from injury.

### 5.1.4 Driving and Commuting

Mine operators employ occupational drivers that are responsible for transporting materials; driving and commuting both to site and within site. Work-related fatigue is reported to be a commonly experienced factor in operators, contributing to their susceptibility to poor health and safety and vehicle-related accidents (Shaikh & Krishnan, 2012). Several studies have investigated this relationship in vehicle operators and occupational drivers within mining. Studies assessing incidence of driver fatigue in the Australian coal mining industry  (Di Milia & Smith, 2004), reported level of driver impairment in shiftworkers and found 13% of participants reported falling asleep at the wheel when driving to shift and 43% when driving home from night shift, with road incidents occurring for 3% of these workers.

In a sample of members in a community which the mine was situated, fatigue was perceived by residents to have a detrimental effect on mining employees' safe driving behaviours and accident risk (Akbar et al., 2018). Supporting this, measurable drowsiness (Adyatama et al., 2019), and an increase in visual and auditory response times, indicating an increased level of fatigue and impaired performance after night shifts was also measured(Ganesan et al., 2022; Milosevic, 1997).

### 5.1.5 Summary of Findings: Research Question 1

The literature surrounding worker fatigue and health and safety outcomes within the mining industry suggests that work characteristics (such as shift work, environmental conditions, and high requirements for driving tasks) can lead to circadian disturbances, irregular eating patterns, chronic sleep loss, sleep disturbances, and poor sleep quality which are significant predictors of both health outcomes (sleep disorders, cardiovascular and gastrointestinal disorders, obesity, metabolic conditions, and impaired cognitive function) and safety outcomes (reduced attention and concentration, risk taking, and work-related errors, violations, and injury outcomes).

In relation to patterns of work scheduling, swing shifts were reported to influence factors such as sleep quality, alertness, and circadian rhythm disruption, which can lead to increased fatigue levels in workers. There are conflicting and inconsistent findings regarding shift length. A small number of studies report psychosocial hazards, exposure to heat and noise, as well as a myriad of individual factors (age, individual health, home environments that are not conducive to good sleep hygiene) can increase fatigue and have adverse health and safety consequences for mine workers. Studies also report detrimental health and safety outcomes (vehicle-related accidents, impaired performance) associated with driver fatigue in mining.

## 5.2 Research question 2: What is the relationship between fatigue and worker mental health in the mining industry?

While worker fatigue has been shown to influence health and safety outcomes, it also has an association with poor mental health outcomes. The literature on worker fatigue and mental health outcomes suggests that various factors, such as hazardous environments, work organisation, psychosocial hazards at work, and individual factors, are significant predictors of poor sleep quality and quantity, which can, in turn, impact mental health outcomes (Pizarro-Montaner et al., 2020). In addition, various factors in the mining industry (e.g. remoteness of mine, absence of family and friends) can have a detrimental effect on sleep and thereby, the mental health of mine workers (Bowers et al., 2018). The following sections synthesise extant literature exploring these relationships.

### 5.2.1 Shift work and Work Scheduling and Mental Health Outcomes

Several studies have sought to investigate the relationship between shift work characteristics and increased risk of psychological distress in mining industry workers. First, a study by Berthelsen et al. (2015) focused on the effects of shift scheduling and psychological distress, reporting that there was no relationship between these two factors. Instead, findings suggest that work characteristics such as the involvement of workers with their shift schedule/roster, managerial leadership, and support may be potential determinants of mental health outcomes. To further elaborate, Turner and Rubin, reveal that the lack of sleep, fatigue, and autonomy surrounding work schedules are psychosocial factors that affect workers' mental health within the mining industry.

With the lack of autonomy surrounding work scheduling, Asare et al. (2021) also identify a positive correlation between mental exhaustion and psychological distress with roster characteristics such as roster type/length and shift length. Moreover, studies that evaluated rostering policies that included adequate sleep durations and considerations of social and personal life were associated with improved well-being, mental health (McLean, 2012) and reduced fatigue (Pelders et al., 2021) in workers. Similarly, these positive outcomes were consistent when workers were consulted or involved with shift schedule changes or rostering (Peetz & Murray, 2011). Robinson et al. (2017) investigated the impact of working arrangements on mineworkers and behavioural issues in their children. Their findings were consistent with Peetz and Murray (2011), suggesting that parents with minimal control over their work schedules influenced aspects of their child’s behaviour which is reflected in greater levels of fatigue, sleep deprivation, emotional exhaustion, and psychological distress in their work.

Studies have also focused on personal and occupational support to promote the well-being and mental health of workers within the mining industry. First, Perring et al. (2014) and Lovell and Critchley (2010) found a positive correlation with efforts to increase social inclusion and community connectedness by implementing recreational and community infrastructure at mining camps where workers were shift workers. The outcomes were associated with enhanced social interactions, improved workers' well-being, and reduced alcohol-consumption. Approaches surrounding personal support also included 24/7 on-site chaplains, which enhanced mental health and reduced psychological distress in shift workers (Ebert & Strehlow, 2017). Moreover, the stress associated with the stigmatisation of mental health is also a relatively influential predictor of high psychological distress among shift workers in the mining industry.

*Extended work shifts*

Evidence suggests a correlation between extended work shifts and negative mental health outcomes (e.g., working shifts over 12 hours duration; James et al, 2018). In the regular (8 hour) day/night shift, studies that evaluated relationships between worker fatigue with mental health reported adverse mental health outcomes, such as subjective sleep complaints (e.g., insomnia), anxiety and depression (Bazazan et al., 2019). Similarly, in extended workday shifts, findings reported higher levels of emotional exhaustion and work-related stress (Le et al., 2022).

### 5.2.2 Individual Factors, Fatigue, and Mental Health Outcomes

Regarding individual factors, shift workers in mining who had sleep disorders were reported to have higher levels of psychological distress (Sadeghniiat-Haghighi et al., 2021), higher fatigue, and higher depression scores. Adverse mental health outcomes were also more pronounced among female shift workers than male shift workers, especially those who had children or wanted to start a family (Pirotta, 2009). In addition, younger shift workers, those with a prior history of health outcomes (e.g., anxiety, depression, alcohol/drug abuse), certain health behaviours (e.g., illicit drug use), and social factors (e.g., poorer social networks) also reported experiencing greater psychological distress (James et al., 2018).

### 5.2.3 Summary of Findings: Research Question 2

The literature surrounding fatigue or sleep-mediated mental health outcomes within the mining industry is significantly smaller in scale and more limited than studies that explore mental health outcomes predicted by other work characteristics (e.g., high work demands, low job control, social isolation) in the mining industry. Nevertheless, studies report the importance of worker autonomy and/or involvement in shift scheduling decisions, the rosters' ability to accommodate sufficient sleep and social inclusion/connectedness, negative implications of extended work shifts, and support structures for shift workers in predicting mine workers' mental health. A number of individual difference factors (health, gender, age, and social factors) were reported to influence the relationship between worker fatigue and mental health outcomes in mining.

## 5.3 Research question 3: Does worker mental health predict fatigue-related safety outcomes in the mining industry?

While the sections above summarised studies that classified worker fatigue as a predictor of health, safety, and mental health outcomes, the relationship between fatigue and mental health can be bi-directional. However, research studying these reverse relationships are rare. The following section outlines findings from four studies that investigated if fatigue, sleep disturbance, and safety outcomes were influenced by poor mental health.

Aligning with population-level studies on this topic, poor mental health was shown to predict poor sleep quality in mine workers. Ning et al. (2020) investigated the effects of occupational stress and circadian rhythms on sleep disorders in workers and found that work-related stress (along with other factors like gender, age, smoking, and marital status), impacted workers' sleep quality (Ning et al., 2020). Their findings were also supported by a study by Jiang et al. (2021), which found that changes in work stressors and coping resources lead to increased sleep disturbances. Studies have also shown that mental health predicts higher fatigue levels in workers in the mining industry with mental health outcomes typically being mediated by sleep disturbance. A review by Pizarro-Montaner et al. (2020) investigated mental health in mine workers and found several consequences. One consequence was that workers who had poor mental health (e.g., those who scored higher on depression scales) experienced work problems, including increased fatigue and injuries. Work-related stress was also positively correlated with workers displaying short- and long-term absences from work, poorer sleep quality and more significant sleep disturbances (Zare et al., 2017).

### 5.3.1 Summary of Findings: Research Question 3

Current research specific to the mining industry has not placed much focus on mental health predicting fatigue and safety outcomes. For those that did study this relationship, high sleep disturbance, fatigue levels, and frequency of injuries were found to be consequences of poor mental health of workers.

# 6. Discussion

## 6.1 Overview

The initial sections of this project report provided a comprehensive fatigue baseline upon which the subsequent stages of the project could build. The baseline included an academic review of fatigue management, a review of current regulations in the area, and identification of controls in a selection of industry fatigue management documentation. This was followed by analysis of fatigue-related incidents in Queensland, NSW, WA and related industries to assist in understanding fatigue as a hazard in Australian mining.

Using the targeted review of current regulatory, industry, and academic research information relating to fatigue management and the analysis of incident data and related statistics, a gap analysis was undertaken to assess the likely effectiveness of current fatigue management processes.

Thereafter, literature reviews were undertaken on relationships between fatigue, health and safety, and mental health within the mining industry.

In the discussion section, a gap analysis of QGN16 against best practice elsewhere is offered, then additional analysis and recommendations are presented by means of two bowties, and overall conclusions are outlined.

## 6.2 Gap analysis of QGN16 against best practice

The earlier comparison in this report used QGN16 as the benchmark; it is also appropriate to undertake a gap analysis of QGN16 against best practice. Much of the fatigue guidance material is dated older than QGN16 (last released in 2013). The code of practice in WA was released in 2006. The SafeWork Australia guideline on Fatigue was also released in 2013. To some extent this has been superseded by the release in 2022 of the code of practice for managing psychosocial hazards at work. The NSW Resource Regulator issued a guide for Fatigue management in 2018, updated in 2019 and Workplace Health and Safety Queensland issued a guide on Preventing and Managing Fatigue-related risk in the workplace in 2020. QGN16 is compared to them.

QGN16 was developed from the then current NSW Fatigue management plan: a practical guide to developing and implementing a fatigue management plan for the NSW Mine Safety Advisory Council that was issued in 2009. Content was also taken from other guidance material current at the time of publishing (2013).

The updated NSW guide contains more information on potential health issues such as: diabetes, high blood pressure, lowered fertility, and harmful drug and alcohol use.  It provides more background information on sleep and the factors affecting it. It describes how one maybe to tell if someone may be fatigued.

Symptoms may include:

- excessive of increased yawning
- falling asleep(different to micro-sleeping)
- headaches
- dizziness
- blurred vision
- poor concentration
- impaired decision making
- slow reflexes
- increased rate of unplanned absences
- regularly arriving later for shift start
- regularly sleeping longer than ‘normal’ on days off

The guide also identifies the need to manage the consequences of fatigue impairment including if a worker becomes fatigued, then control measures should remove the impaired workers from high-risk work or reduce the consequences of fatigue related error. For example:

- not scheduling high risk work during high risk points in the shift(circadian lows) or high risk points in the roster cycle.
- Using technology which isolates workers/stops operation when fatigue signs are detected
- Establishing arrangements for workers and supervisors to identify worker fatigue and taking appropriate action to remove the worker from work where a fatigue related error could result in an incident’
- Rotate workers to lower risk tasks when symptoms of fatigue are identified.

Appendix 8 of the guide outlines example controls for the most common fatigue risk factors.  The guide also employs a bow-tie to help identify control measures (shown in Figure 5 below).

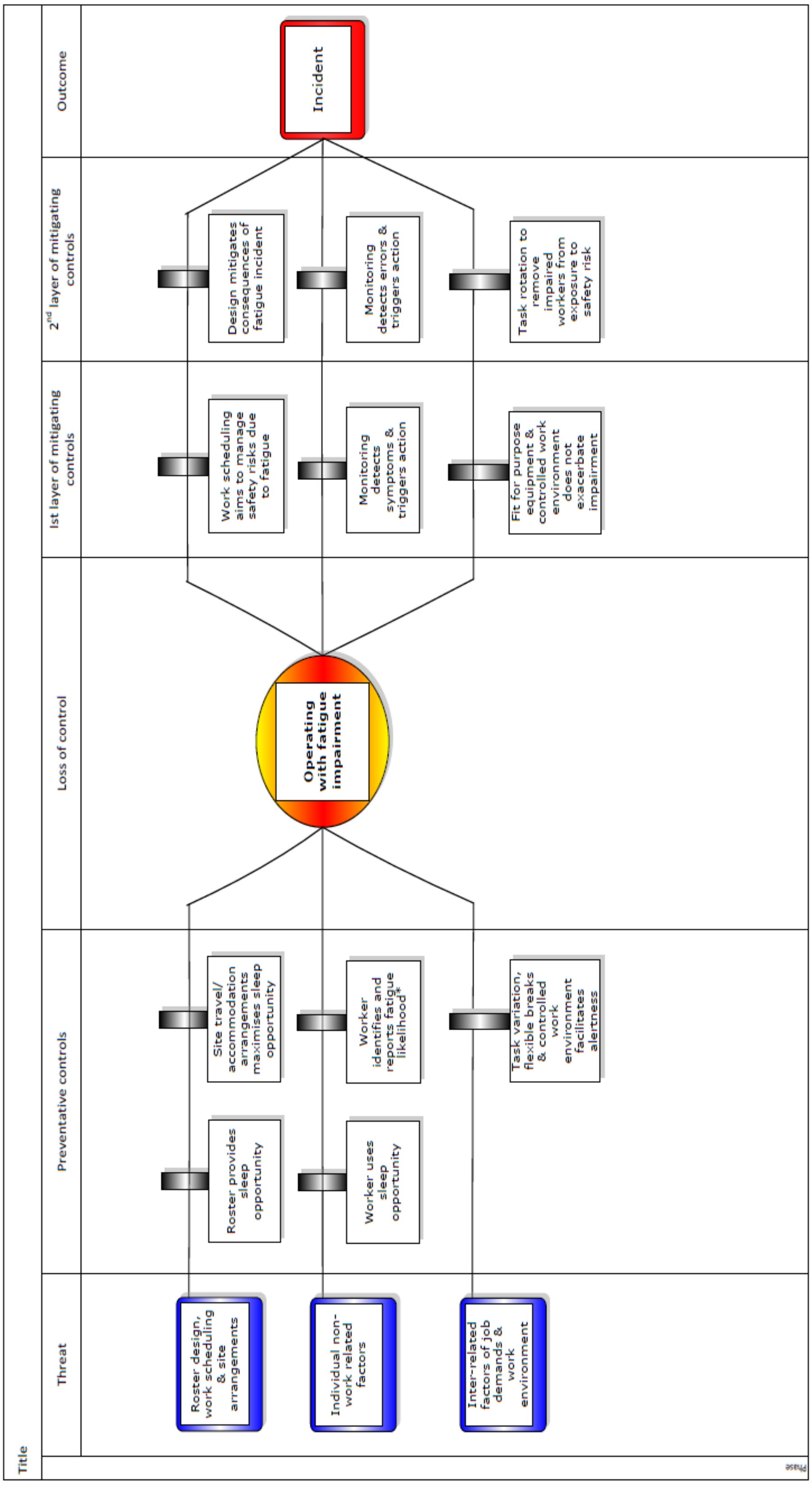



**Figure 5**. Example bow-tie from NSW Resource Regulator Guide to Fatigue Management.

Another feature the guide is the description of ways to monitor the effectiveness of the controls and the need to regularly review the control measures.  Examples of useful measures cited included:

- Hours worked over shifts, weeks, months
- Workers not presenting fit for work due to fatigue
- Assessment of an individuals' impairment due to fatigue
- Changes in shift patterns, including novel events, e.g. shutdowns
- Outcomes of investigations that identify fatigue as a factor
- Current information  on fatigue hazards and risks
- Actual breaks between shifts and blocks of shifts
- Commuting /travel times
- Training records

The NSW guide stresses the importance of monitoring including selecting the right measure, the frequency of measurement, how will the monitoring be done and prompt investigation of any issues of concern.

The guide also plays special attention to risk factors associated with the use of contractors (Appendix 2), especially those employed to undertake safety critical tasks.  Contractors may work across a number of sites before taking a break and be employed to undertake specialist tasks such as during a shutdown for major maintenance work.

The guide offers a number of tools to assist in the assessment of fatigue (Appendix 3) including a fatigue opportunity calculator, a fatigue likelihood calculator, and the Sam-Pirelli fatigue checklist.  The guide also promotes the concept of defences in depth (see diagram 6 below sourced from Dawson D et al, 2011).

The fatigue risk management chart in appendix 8 is very similar to that in the WA code of practice and the tables of risk factors already in QGN-16.  It includes references to repetitive work and exposure to hazardous substances and atmospheric contaminants, noise, vibration and extreme temperatures as risk factors.

Workplace Health and Safety Queensland issued a guide on Preventing and managing fatigue-related risk in the workplace in 2020. It provides a useful overview of fatigue related signs and symptoms (Table 20 below) as well as the consequences of fatigue (Table 21). The document places emphasis on leadership as a key component of the fatigue risk management process. As with the NSW document it emphasises the need to collect and analyse data relating to fatigue related hazards. These could include: hazard reporting database, hours of work records, incident and investigation data, records of current and recurring industrial issues in the workplace, data on various types of leave usage, minutes of workplace meetings, workplace health and safety issues register, workers compensation claims, workplace inspection records and action plans, sleep data, performance data, medical and health records and audit records.

The document advocates risk assessment and management using the standard 5 x 5 matrix for risk ranking. Chapter 14 deals in detail with monitoring and evaluation. Dawson’s defences in depth model is shown in Figure 6, fatigue related signs and symptoms are shown in Table 20, consequences of fatigue (from Workcover) are shown in Table 21 and lead/lag indicator examples from Workcover are shown in Table 22.

**Figure 6.** Defences in depth fatigue risk management model (Dawson et al, 2011)

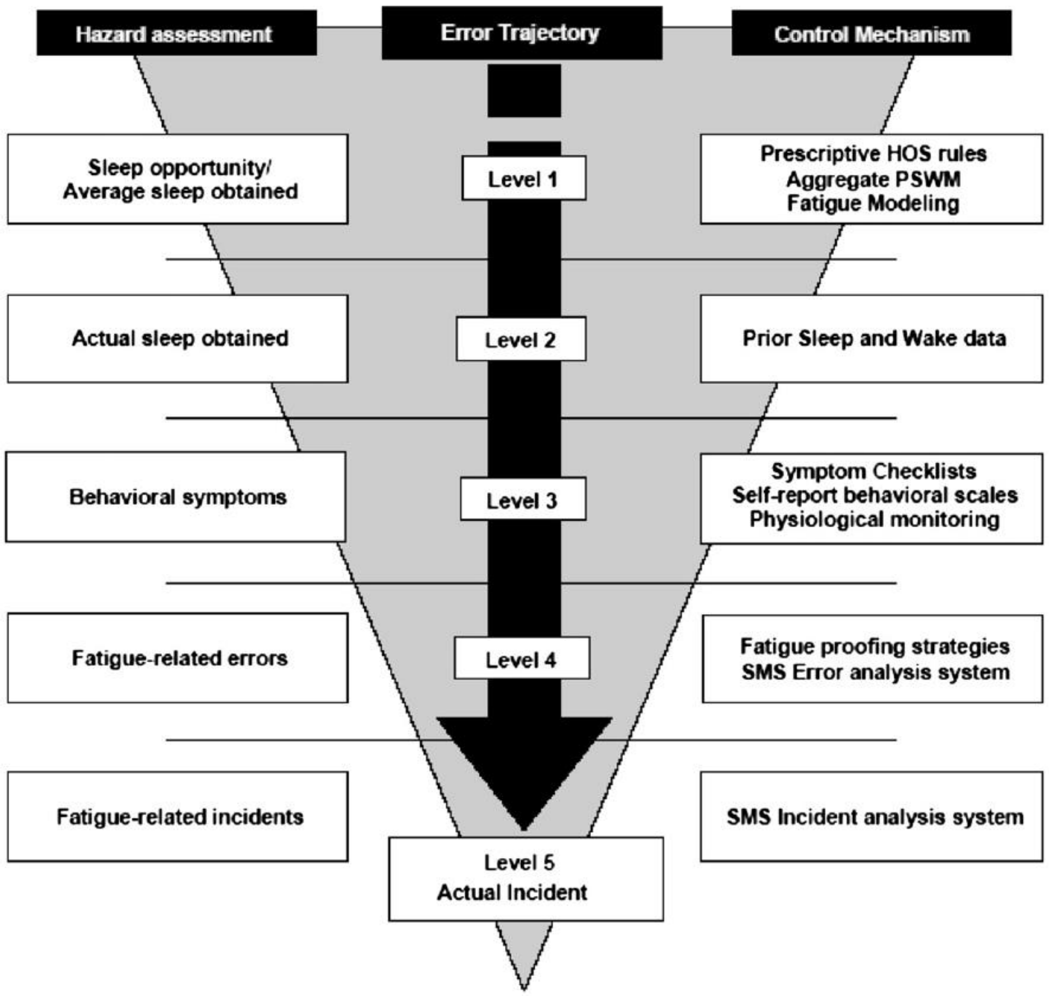


**Table 20.** Fatigue related signs and symptoms (Workcover, 2020).

| Physical | Cognitive | Emotional |
|---|---|---|
| Yawning | Difficulty concentrating on tasks | More quiet than usual |
| Increased blink rate | Lapses in attention | Withdrawn |
| Heavy eyelids | Difficulty remembering | Reduced motivation |
| Blurred vision | Failure to communicate important information | Lacking energy |
| Head drooping | Risk taking behaviour | Decreased tolerance |
| Slower reaction time | Disorganisation | Mood disturbances |
| Impaired hand eye coordination | Lack of situational awareness | Emotional outbursts |
| Headache | Accidently doing the wrong thing (error) | Irritability |
| Muscle aches and cramps | Accidently not doing the planned thing (omission) | |

**Table 21**. Consequence of fatigue (Workcover, 2020)

| Individual | Workplace | Community |
| --- | --- | --- |
| Poorer physical and psychological health<br>Impacts to cognitive functioning<br>Impacts to short-term memory function<br>Increased likelihood of social alienation<br>Increased instances of relationship problems<br>Increased likelihood of being involved in an incident<br>Impacts to work-related performance | Increased fatigue-related error and incidents<br>Increased mortality rates<br>Increased costs associated with incident management<br>Increased levels of absenteeism and lost time<br>Increased levels of presenteeism (i.e. coming to work despite injury, illness or other, resulting in reduced productivity)<br>Poorer workplace morale and satisfaction<br>Impacts to company image and reputation | Increased potential for incidents to occur in the community (i.e. road crashes)<br>Increased need for trauma counselling services<br>Increased use of medical facilities and allied health services<br>Broader ripple effects of serious injury, disability and death in the community |

**Table 22.** Lead and lag indicator examples (Workcover, 2020).

| Lead indicators | Lag indicators |
|---|---|
| Percentage of unfilled positions. | Percentage of shifts that exceed the organisation's tolerable levels in planned roster and actual hours worked. |
| Percentage of workers diagnosed with a medical condition that may impact on sleep or alertness at work. | Percentage of hours worked on overtime. |
| Percentage of existing fatigue risk assessments and risk management plans reviewed within scheduled dates. | Number of call outs per on call shift. |
| Percentage of workers that have been provided with fatigue risk management training. | Number of self-reports related to fatigue. |
| Percentage of officers that have been provided with fatigue risk management training. | Number of observations (by supervisors, managers or peers) related to fatigue. |
| Percentage of shifts that comply with rostered work hours. | Percentage of near miss reports that make attribute fatigue, overtime, call outs or workload as a contributing or causal factor. |
| Percentage of hazard reports related to fatigue. | Percentage of near misses or incidents occurring during times in the roster where the likelihood of fatigue- related impairment is increased. |
| Percentage of investigation reports that assess the contribution of fatigue. | Number of individual risk assessments triggered as a result of a self-report or observation (by supervisor, manager or peer). |
| Percentage of workers who report a need to change tasks or take more frequent breaks. | Frequency of sick leave taken during times in the roster where the likelihood of fatigue-related impairment is increased. |
| Percentage of overtime worked. | Number of psychological injury reports and claims. |

The document also identifies a series of nationally recognised training competencies relating to fatigue management:

- TLIF0006 – Administer a fatigue risk management system
- TLIF3063 – Administer the implementation of fatigue management strategies
- TLIF0005 – Apply a fatigue risk management system
- TLIF2010 – Apply fatigue management strategies
- TLIF0007 – Manage a fatigue risk management system
- TLIF4064 – Manage fatigue management policy and procedures.

The guide also offers a fatigue factors checklist, organisational self-assessment tool, sample worker consultation survey, an individual fatigue risk assessment and workplace safety plan to assist managers assess the risks and the level of support needed to assist a worker affected by fatigue and a fatigue-related investigation tool to guide an investigation into an incident that may have involved fatigue.

It is recommended that these tools be considered for potential use in the Queensland Mining Industry.

## 6.3 Bow-Tie Analysis

This section provides visual evidence to support the information given throughout this report, especially in Section 6.2 that provided a gap analysis of QGN16 against best practice. Two bow-ties are shown, Figures 7a and 7b represent the threat lines and preventative controls, and the consequences and mitigating controls, respectively, that are listed in QGN16. Figures 8a and 8b show the same elements for a bow-tie that was developed from controls and recommendations given in more recent mining and non-mining fatigue guidance documents, as follows:

- NSW Resources Regulator's Guide to Fatigue Management (2019)
- A fatigue bow-tie from a leading Australian mining company, being one of the mining companies that provided information for the analysis conducted in Section 2.3 of this report.
- Workplace Health & Safety Queensland's Preventing and Managing Fatigue-related Risk in the Workplace (2020)
- Transport Canada's Duty and Rest Rules for Railway Operating Employees (2020)

- US Government's, Federal Railroad Administration's Fatigue Risk Management Programs for Certain Passenger and Freight Railroads (2022)

In this way, we aim to provide a visual representation of how fatigue management has progressed since the release of QGN16 in 2013.

## QGN16 bow-tie

In developing the first bow-tie, we took the controls given to manage *Direct and Contributing Risk Factors*, that were listed in QGN16 (pp. 36-44) and arranged them according to whether they were preventative or mitigating controls. They were arranged around the unwanted event, "Cumulative and acute fatigue affecting work performance".

In a bow-tie analysis, the unwanted event is the centre (or knot) of the bow-tie. On the left and right side of the knot are listed the causes and consequences of that event, respectively. Each of the causes and consequences are linked to a series of controls that have the potential to either prevent the event from occurring (preventative controls) or reduce the severity of the consequences (mitigating controls). This method is commonly used by mining companies in Australia to assist them in the implementation of safer operations.

QGN16 did not list controls according to causes, so instead we arranged them according to the five common factors that the document reported contributed to the development of fatigue. They could be likened to threat-lines. They were:

- Work scheduling and planning
- Work environment conditions
- Excessive commuting times
- Mental and physical demands of work
- Individual and non-work factors

There were two consequences: 1) safety incidents on site or during commute due to influence of fatigue and 2) long-term health problems due to cumulative influence of fatigue.

As can be seen in Figures 7a and 7b, most of the controls listed in the document were preventative controls, and most of the preventative controls fell under the *work scheduling and planning* threat line.

Also evident is that many of the controls would now be considered supporting actions rather than controls (e.g., training, management plan). In 2015, the International Council on Mining and Mineral's provided a framework for OHS control management which defines a control as an act, object (engineered) or system (combination of act and object) intended to *directly* (or *of itself*) prevent or mitigate an unwanted event (ICMM, 2015, 2016). In this view, a control should be specifiable, measurable and auditable.

## Current leading practice bow-tie

This bow-tie represents a compilation of the controls from QGN16 and those taken from newer mining and non-mining fatigue guidance documents, as listed above. Our aim was to develop a body of controls to manage the risks of fatigue, which was 1) for the mining industry, and that represented 2) current understanding, and 3) leading practice.

In Figures 8a and 8b, the different coloured text indicates the source of the controls:

- Black text QGN16
- Blue text NSW Resources Regulator's Guide
- Purple text Australian mining company bow-tie example
- Orange text Transport Canada's Railway guidance
- Red text RISKGATE

Riskgate was used because it offered important controls for mobile equipment (e.g., haul trucks) not given in other documents on road design and bunds, berms and delineators.

For easy comparison, the same five threat lines are used for both bow-ties. Like the QGN16 bow-tie, most of the preventative controls were categorised as being in the work scheduling and planning threat line. However, many of the QGN controls have been replaced and now more aligned with the newer ICMM definition of a control.

They directly address factors contributing to fatigue such as night shifts, overtime, early morning starts, consecutive shifts, shift rotation and breaks.

In the *work conditions* threat line, a number of the controls concern minimising the risk of fatigue through ventilation, temperature control, vibration matting, seat suspension, work area lighting, etc. Also, added to this threat line are controls specifically addressing mobile equipment.

None of the newer documents we reviewed had a list of specific controls for commuting, so the newer bow-tie includes controls carried over from QGN16. Added to the *Individual and non-work factors* threat line is a group of controls focused on misuse of drugs and or alcohol.

An important addition to the bow-tie is a consequence that concerns impaired decision making and includes self-reporting of fatigue, peer detection, communication channels, procedures to verify decisions, and TARPS for principal hazards to guide decision making as mitigating controls. This consequence and its controls suggests that the industry is growing in its understanding of fatigue, with one mining company now formally recognising its impact on employee's decision making and judgement.

The NSW Resources Regulator's fatigue bow-tie, included two layers of mitigating controls for the safety incident consequence. The first layer aims to detect and mitigate symptoms of fatigue, while the next layer attempts to mitigate errors in performance caused by fatigue. Fatigue detection technology is listed as a mitigating control, as are collision management systems.

The mitigating controls for the *long term health problems due to cumulative influence of fatigue* now highlights mental health as a potential outcome. Also, there are many more mitigating controls listed for it compared to the earlier bow-tie.

It was difficult to translate the rail-oriented controls given in Transport Canada's Duty and Rest Rules for Railway Operating Employees document to a mining context. However, useful additions from the document included employee's self-reporting of fatigue and the company's required response to it.

### Bow-tie Summary

Overall, the changes in the bow-ties across time show a maturing in the mining industry's understanding and management of risks associated with fatigue. The results also support those previously identified in the report, including:

- better monitoring the long-term health effects of fatigue,
- a consideration of mental health outcomes, and
- a greater use of fatigue detection technologies.

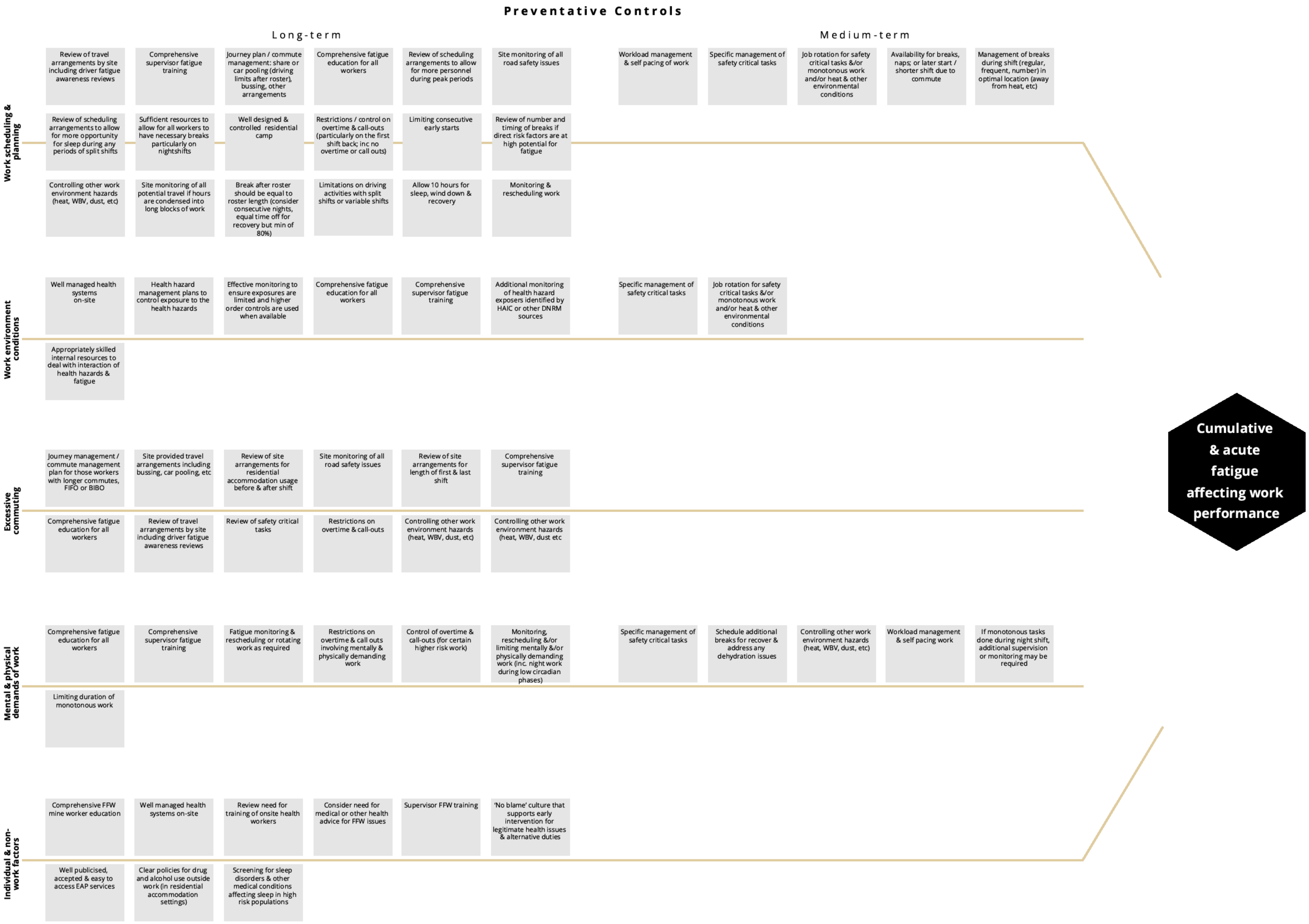



**Figure 7a:** QGN 16 Bow-Tie (Preventative controls)

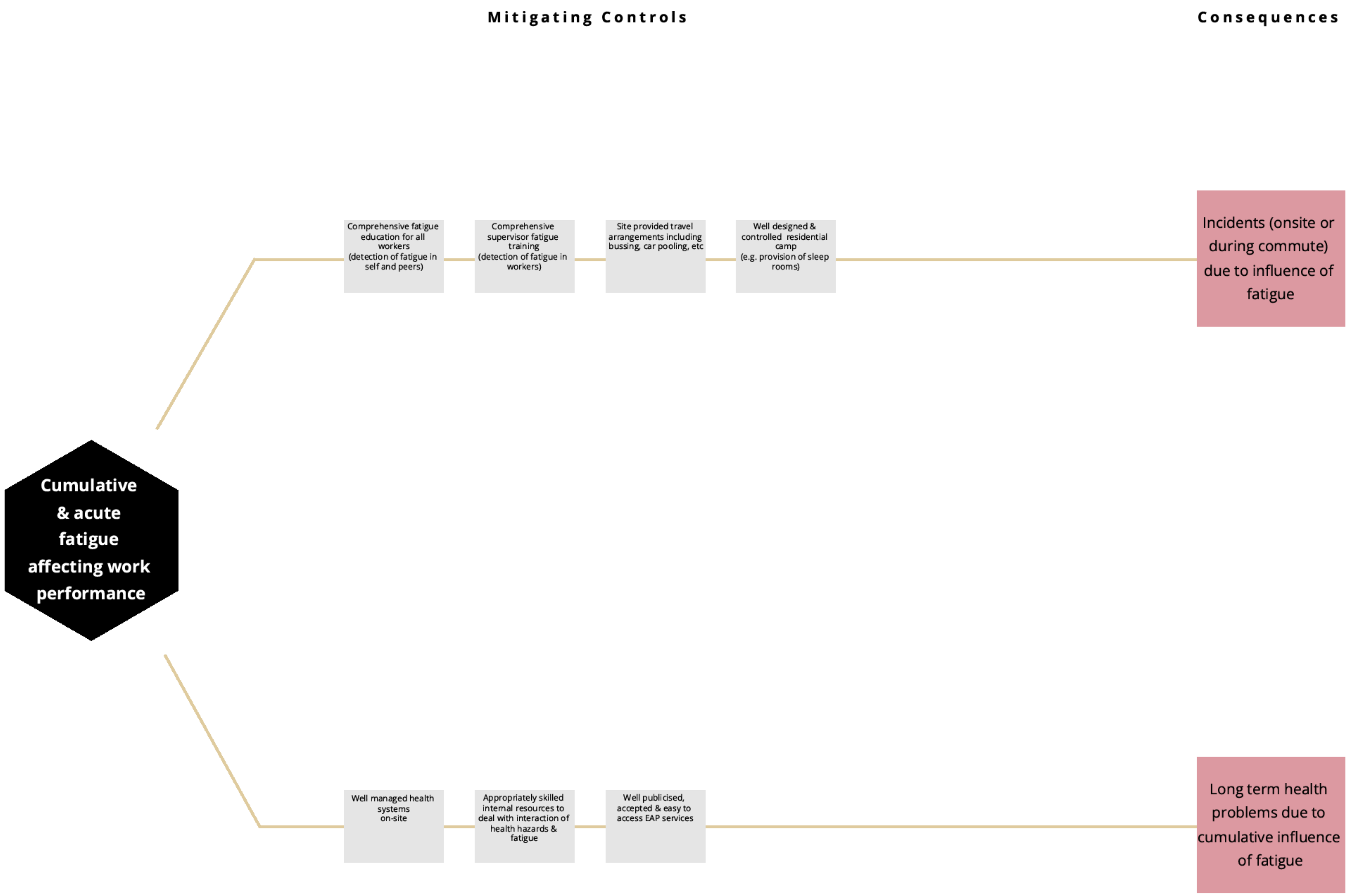



**Figure 7b:** QGN 16 Bow-Tie (Mitigating controls)

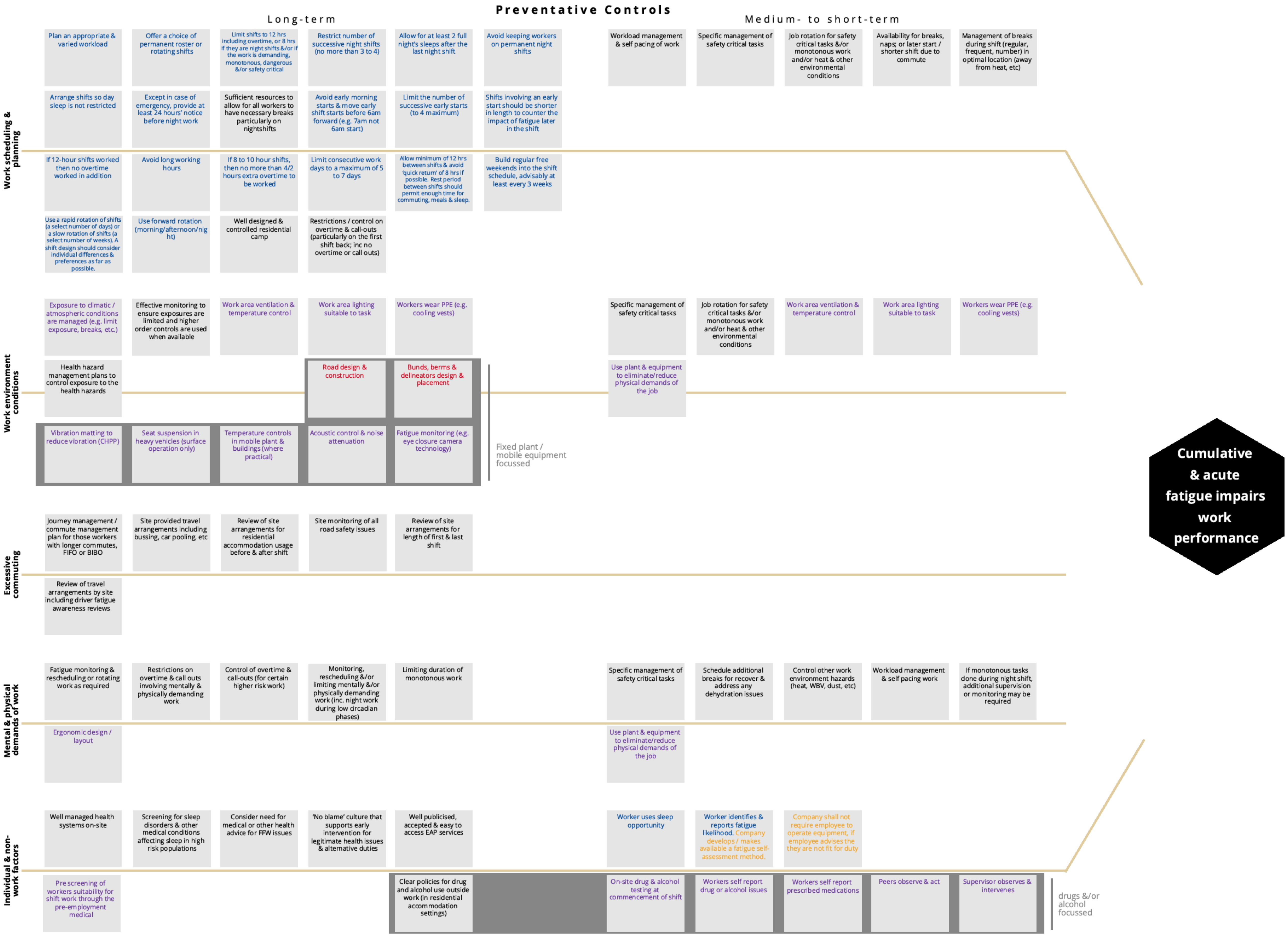



**Figure 8a:** Leading Practice fatigue management Bow-Tie (Preventative controls)

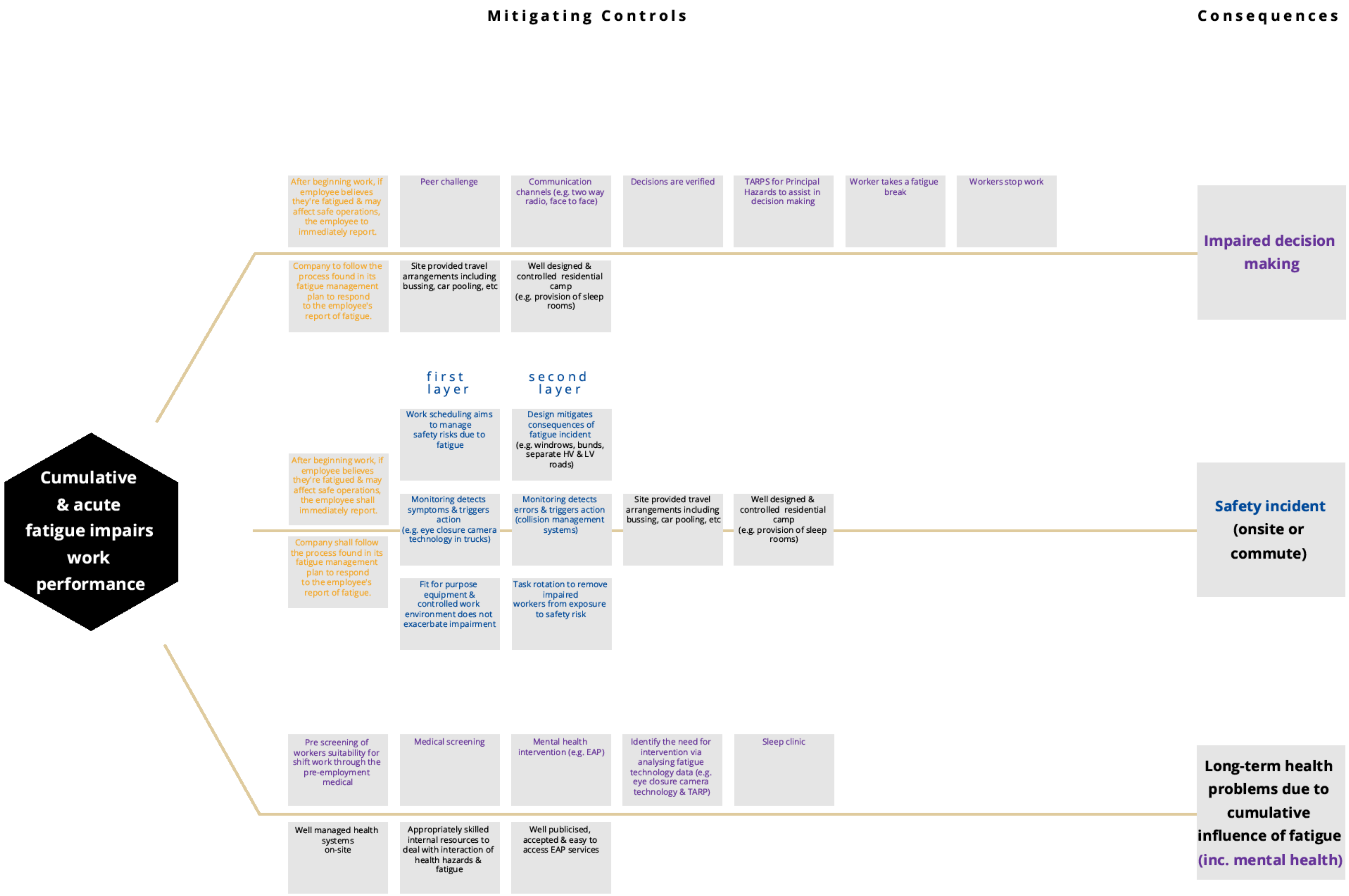



**Figure 8b:** Leading Practice fatigue management Bow-Tie (Mitigating controls)

## 6.4 Conclusions

The work used a wide range of approaches to better understand fatigue, and fatigue management, in Queensland mining. It has also been one of the first projects to examine the relationships between fatigue, safety and mental health in mining.

To better understand the prevalence, analysis of fatigue-reported incident data from Queensland, NSW and WA was undertaken. From the Queensland data, around 2.5% of all reported notifiable incidents included fatigue as a factor.

Most reported fatigue incidents occurred when driving heavy vehicles on surface coal mines. There was a drop in fatigue-reported vehicle events in 2020 and 2021 compared to previous years. More incidents occurred in the last few hours of a shift. Two thirds of vehicle-related incidents occurred when operators were on night shift.

The fatigue management literature review showed that many types of interventions were used in mining and related industries, such as training, lighting and environmental conditions, but the greatest number of studies focused on rostering and shift design.

The regulatory review examined the management of fatigue as expressed in Acts, Regulations, Codes, Guidelines and Guidance Notes to identify how fatigue was captured in Queensland (including in QGN16) as well as leading practice elsewhere.

An industry information review examined fatigue management at seven mine sites. It showed that sites generally followed QGN16. Areas that may require more work include monitoring the long term health effects of fatigue and verification of fatigue controls.

Additional literature reviews explored the relationships between fatigue, health and safety, and mental health in mining. Current mining industry research has not placed much focus on mental health predicting fatigue and safety outcomes; those that did study this relationship found high fatigue levels, sleep disturbances, and frequency of accidents to be consequences of poor mental health of workers.

The work closed by examining the gaps in Queensland fatigue management. Two bow-ties were created: one examining current fatigue management controls from QGN16, and a second showing leading practice in fatigue management as possible additional controls. These additional controls that could be incorporated into future versions of a Queensland fatigue management guidance note include a better consideration of mental health outcomes, and a greater use of fatigue detection technologies. Overall, the changes in the bow-ties across time show a maturing in the mining industry's understanding and management of risks associated with fatigue

The key conclusions of the work are:

1. ***Fatigue Incident Data Collection***: It is highly likely that registered fatigue incident numbers represent under-reporting, so further work to help collect more comprehensive fatigue incident data in Queensland is advised.
2. ***Fatigue Incidents***: Prioritised action plans to focus on fatigue risks for heavy vehicle drivers on surface mines during night shifts are proposed, especially during their first few shifts of the roster cycle.
3. ***Fatigue Management***: It is proposed that the effectiveness of fatigue management controls should be verified, and that controls need to be regularly reviewed. This issue is particularly important given the challenges sometimes faced when Queensland workplaces wish to implement fatigue management controls but are thwarted by mandated thresholds for agreement in consultation processes, so a review of legislation against best practise for continuous improvement is proposed. Additionally, worker consultation was a key area emerging in leading practice, so greater consultation in developing fatigue management and rostering arrangements is advised. Equally, greater use of enhanced lighting interventions in mining fatigue management is advocated. Overall, well-designed studies to evaluate the efficacy of fatigue management interventions in the mining industry are needed.
4. ***Industry Fatigue Management Gaps***: From the mine site document reviews, better monitoring of the long-term health effects of fatigue, a consideration of mental health outcomes, a greater use of fatigue detection technologies (with associated psychological safety and health support systems), and a stronger corporate emphasis of the importance of mining fatigue management are proposed.
5. ***Mental Health and Fatigue***: Further work by the industry in the mental health area is needed, particularly examining fatigue as a mechanism in mental health outcomes, and mental health as a potential predictor of fatigue and health and safety outcomes.

6. ***Mentally Healthy Workplaces Toolkit***: Following other states, it is proposed that a toolkit be developed by government and industry stakeholders to assist workplaces to assess psychosocial hazards and risk as they may relate to fatigue and mental health outcomes. This toolkit could also be used to inform prevention activities as well as being used during incident investigations or during major mine site changes (such as the introduction of automation).

# 7. References


**Parts 1A-1C**

Adyatama, A., Syaifullah, D. H., & Moch, B. N. (2019). *Developing a Dump Truck Drivers Occupational Fatigue Assessment Model as Hauling Workplace Accidents Prevention: Study Case at Indonesia's Coal Mining Company* Proceedings of the 2019 5th International Conference on Industrial and Business Engineering, Hong Kong, Hong Kong. https://doi.org/10.1145/3364335.3364361

Asare, B. Y.-A., Kwasnicka, D., Powell, D., & Robinson, S. (2021). Health and well-being of rotation workers in the mining, offshore oil and gas, and construction industry: a systematic review. *BMJ Global Health*, *6*(7), e005112. https://doi.org/10.1136/bmjgh-2021-005112

Baker, A., Heiler, K., & Ferguson, S. A. (2001). The effects of a roster schedule change from 8- to 12-hour shifts on health and safety in a mining operation. *J Hum Ergol (Tokyo)*, *30*(1-2), 65-70.

Barnes, C. M., & Wagner, D. T. (2009). Changing to Daylight Saving Time Cuts Into Sleep and Increases Workplace Injuries. *J Appl Psychol*, *94*(5), 1305-1317. https://doi.org/10.1037/a0015320

Baulk, S. D., Fletcher, A., Kandelaars, K. J., Dawson, D., & Roach, G. D. (2009). A field study of sleep and fatigue in a regular rotating 12-h shift system. *Appl Ergon*, *40*(4), 694-698. https://doi.org/10.1016/j.apergo.2008.06.003

Bauerle, T. J., Sammarco, J. J., Dugdale, Z. J., & Dawson, D. (2021). The human factors of mineworker fatigue: An overview on prevalence, mitigation, and what's next. *Am J Ind Med*. https://doi.org/10.1002/ajim.23301

Bongers, D. (2009). *Operator Fatigue Detection and Countermeasure Development* (ACARP Project C15040).

Bjorvatn, B., Kecklund, G., & Åkerstedt, T. (1999). Bright light treatment used for adaptation to night work and re-adaptation back to day life. A field study at an oil platform in the North Sea. *J Sleep Res*, *8*(2), 105-112. https://doi.org/10.1046/j.1365-2869.1999.00146.x

Bjorvatn, B., Stangenes, K., Oyane, N., Forberg, K., Lowden, A., Holsten, F., & Akerstedt, T. (2006). Subjective and objective measures of adaptation and readaptation to night work on an oil rig in the North Sea. *Sleep*, *29*(6), 821-829. https://doi.org/10.1093/sleep/29.6.821 `

Bjorvatn, B., Stangenes, K., Øyane, N., Forberg, K., Lowden, A., Holsten, F., & Åkerstedt, T. (2007). Randomized placebo-controlled Field Study of the Effects of Bright Light and Melatonin in Adaptation to Night Work. *Scand J Work Environ Health*, *33*(3), 204-214. https://doi.org/10.5271/sjweh.1129

Brake, D. J., & Bates, G. P. (2001). Fatigue in industrial workers under thermal stress on extended shift lengths. *Occup Med (Lond)*, *51*(7), 456-463. https://doi.org/10.1093/occmed/51.7.456

Butlewski, M., Dahlke, G., Drzewiecka, M., & Pacholski, L. (2015). Fatigue of Miners as a Key Factor in the Work Safety System. *Procedia Manufacturing*, *3*, 4732-4739. https://doi.org/https://doi.org/10.1016/j.promfg.2015.07.570

Castellucci, H. I., & Altamirano, I. (2018). Changing the shift system in a mining company: An intervention study [https://doi.org/10.1002/hfm.20725]. *Human Factors and Ergonomics in Manufacturing & Service Industries*, *28*(2), 81-89. https://doi.org/https://doi.org/10.1002/hfm.20725

Chimamise, C., Gombe, N. T., Tshimanga, M., Chadambuka, A., Shambira, G., &

Chimusoro, A. (2013). Factors associated with severe occupational injuries at mining company in Zimbabwe, 2010: a cross-sectional study. *Pan Afr Med J*, *14*, 5. https://doi.org/10.11604/pamj.2013.14.5.1148

Davis, W., & Aguirre, A. (n.d.). *Shift Scheduling & Employee Involvement: The Key to Successful Schedules*. CIRCADIAN.

Dawson D et al, (2011). A new approach to reducing fatigue-related risk using the principles of error management, *Sleep Medicine Reviews*, doi:10:1016/j.smrv.2011.05.004

d'Ettorre, G., Pellicani, V., Vullo, A., Ceccarelli, G., & La Torre, G. (2020). Preliminary assessment of rotating shiftwork risk in a 24-hours metal industry. *Work*, *65*(2), 369-375. https://doi.org/10.3233/wor-203089

De, S., Almberg, K. S., Cohen, R. A., & Friedman, L. S. (2020). Injuries during the first hour at work in the U.S. mining industry. *Am J Ind Med*, *63*(12), 1124-1133. https://doi.org/10.1002/ajim.23186

Di Milia. L., & Smith. P. (2004). *The Underlying Causes and Incidence of Driver Fatigue in a Shiftwork and Non-shiftwork Population*. Central Queensland University.

Donoghue, A. M., Sinclair, M. J., & Bates, G. P. (2000). Heat exhaustion in a deep underground metalliferous mine. *Occup Environ Med*, *57*(3), 165-174. https://doi.org/10.1136/oem.57.3.165

Donoghue, A. M., Frisch, N., & Olney, D. (2014). Bauxite mining and alumina refining: process description and occupational health risks. *J Occup Environ Med*, *56*(5 Suppl), S12-17. https://doi.org/10.1097/jom.0000000000000001

Duchon, J. C. (1992). *The effects of extended workdays in an underground mine: Analysis of psychomotor and physiological functioning* (Publication Number 9311931) [Ph.D., Illinois Institute of Technology]. ProQuest Dissertations & Theses Global. Ann Arbor. https://www.proquest.com/dissertations-theses/effects-extended-workdays-underground-mine/docview/303984611/se-2?accountid=14723

Duchon, J. C., Smith, T. J., Keran, C. M., & Koehler, E. J. (1997). Psychophysiological manifestations of performance during work on extended workshifts. *International Journal of Industrial Ergonomics*, *20*(1), 39-49. https://doi.org/https://doi.org/10.1016/S0169-8141(96)00030-3

Dugdale, Z., Eiter, B., Chaumont Menéndez, C., Wong, I., & Bauerle, T. (2022). Findings from a systematic review of fatigue interventions: What's (not) being tested in mining and other industrial environments. *Am J Ind Med*, *65*(4), 248-261. https://doi.org/10.1002/ajim.23334

Ebert, A., & Strehlow, K. (2017). Does on-site chaplaincy enhance the health and well being of fly-in, fly-out (FIFO) personnel? *Health Promot J Austr*, *28*(2), 118-122. https://doi.org/10.1071/he16019

Eiter, B. M., Steiner, L., & Kelhart, A. (2014). Application of fatigue management systems: small mines and low technology solutions. *Min Eng*, *66*(4), 69-75.

Friedman, L. S., Almberg, K. S., & Cohen, R. A. (2019). Injuries associated with long working hours among employees in the US mining industry: risk factors and adverse outcomes. *Occupational and Environmental Medicine*, *76*(6), 389. https://doi.org/10.1136/oemed-2018-105558

Gander, P. H., Marshall, N. S., Bolger, W., & Girling, I. (2005). An evaluation of driver training as a fatigue countermeasure. *Transportation Research Part F: Traffic*

*Psychology and Behaviour*, *8*(1), 47-58. https://doi.org/https://doi.org/10.1016/j.trf.2005.01.001

Ganesan, S., Manousakis, J. E., Mulhall, M. D., Sletten, T. L., Tucker, A., Howard, M. E., Anderson, C., & Rajaratnam, S. M. W. (2022). Sleep, alertness and performance across a first and a second night shift in mining haul truck drivers. *Chronobiol Int*, *39*(6), 769-780. https://doi.org/10.1080/07420528.2022.2034838

Guerreiro, R. C., Silva, A., Da Silva, F. R., Brant, V. M., Amaral, A. S., Cavalcante, G. T. S., Lobo, I. L. B., Andrade, H. D. A., Andrade, T. C., & De Mello, M. T. (2022). Sleep behavior of shift workers who maintained external work activities during the period of social restriction of COVID-19 [Conference Abstract]. *Sleep Science*, *15*, 30. https://www.embase.com/search/results?subaction=viewrecord&id=L638458371&from=export

Horberry, T., Hartley, L., Krueger, G. & Mabbott, N. (2001). Fatigue detection technologies for drivers: a review of existing operator-centred systems. *IEE Conference Publication,* 321–326. https://doi.org/10.1049/cp:20010483

Heiler, K. (2001*). Rostering and Shiftwork Arrangements in the Mining Industry: Key Trends*. The University of Sydney.

Jiang, Y., Li, P., Zhong, L., Liu, B., Gao, X., Ning, L., Lian, Y., & Liu, J. (2021). The influence of changes in work stressors and coping resources on sleep disturbances: evidence from the OHSPIW cohort study. *Sleep*, *44*(8), zsab039. https://doi.org/10.1093/sleep/zsab039

Kerin, A., & Aguirre, A. (2005). Improving health, safety, and profits in extended hours operations (shiftwork). *Ind Health*, *43*(1), 201-208. https://doi.org/10.2486/indhealth.43.201

Kirsch, P., Goater, S., Harris, J., Sprott, D. & Joy, J. (2012). RISKGATE: Promoting and redefining best practice for risk management in the Australian coal industry, 12th Coal Operators' Conference, University of Wollongong & The Australasian Institute of Mining and Metallurgy, 2012, 315-325

Langdon, R. R., Biggs, H. C., & Rowland, B. (2016). Australian fly-in, fly-out operations: Impacts on communities, safety, workers and their families. *Work*, *55*(2), 413-427. https://doi.org/10.3233/wor-162412

Legault, G., Clement, A., Kenny, G. P., Hardcastle, S., & Keller, N. (2017). Cognitive consequences of sleep deprivation, shiftwork, and heat exposure for underground miners. *Appl Ergon*, *58*, 144-150. https://doi.org/10.1016/j.apergo.2016.06.007

Leary, C., & Cliff, D. (2003). A Study of the Health and Safety Aspects of Fatigue, Shiftwork and Rosters at Pasminco Century Mine, in the Proceedings of the Queensland Mining Industry Health and Safety Conference 2002, 4 – 7 August, Townsville, Queensland, Australia.

Li, J., Qin, Y., Yang, L., Wang, Z., Han, K., & Guan, C. (2021). A simulation experiment study to examine the effects of noise on miners' safety behavior in underground coal mines. *BMC Public Health*, *21*(1), 324. https://doi.org/10.1186/s12889-021-10354-2

Ljoså, C. H., & Lau, B. (2009). Shiftwork in the Norwegian petroleum industry: overcoming difficulties with family and social life - a cross sectional study. *J Occup Med Toxicol*, *4*, 22. https://doi.org/10.1186/1745-6673-4-22

Lovell, J., & Critchley, J. (2010). Women living in a remote Australian mining community: exploring their psychological well-being. *Aust J Rural Health*, *18*(3), 125-130. https://doi.org/10.1111/j.1440-1584.2010.01143.x

Lowden, A., Akerstedt, T., & Wibom, R. (2004). Suppression of sleepiness and melatonin by bright light exposure during breaks in night work. *J Sleep Res*, *13*(1), 37-43. https://doi.org/10.1046/j.1365-2869.2003.00381.x

Mabbott, N. (2002). *Procedures and Devices to Monitor Operator Alertness Whilst Operating Machinery in Open Cut Coal Mines - Stage 3.* (RC97043)

Mabbott, N., & Lloyd, B. (2003). *Operator Fatigue Through Nightshifts in Succession* (RC07258).

Marcin, B., Grzegorz, D., Milena, D.-D., Krzysztof, H., Adam, G., & Brigita, G. (2020). Use of the Methodology of Network Thinking for a Fatigue Criteria Investigation Based on the Example of Mining Companies. *Tehnički vjesnik*, *27*(4), 1037-1043.

Maisey, G., Cattani, M., Devine, A., Lo, J., & Dunican, I. C. (2020). The Sleep of Shift Workers in a Remote Mining Operation: Methodology for a Randomized Control Trial to Determine Evidence-Based Interventions. *Front Neurosci*, *14*, 579668. https://doi.org/10.3389/fnins.2020.579668

Merkus, S. L., Huysmans, M. A., Holte, K. A., van Mechelen, W., & van der Beek, A. J. (2017). An active transition from offshore work to family life: Activities that may impact recovery. *Work*, *58*(3), 371-381. https://doi.org/10.3233/wor-172631

Mehta, R. K., Smith, A., Williams, J. P., Camille Peres, S., & Sasangohar, F. (2019). Investigating Fatigue in Offshore Drilling Workers: A Qualitative Data Analysis of Interviews. *IISE Transactions on Occupational Ergonomics and Human Factors*, *7*(1), 31-42. https://doi.org/10.1080/24725838.2019.1593896

Minerals Industry Safety and Health Centre. (2005). *Work Breaks and Rest Periods*.

Muller, R., Carter, A., & Williamson, A. (2008). Epidemiological diagnosis of occupational fatigue in a fly-in–fly-out operation of the mineral industry. *Annals of Occupational Hygiene*, *52*(1), 63-72.

Nielsen, M. B., Hystad, S. W., & Eid, J. (2016). The Brief Norwegian Safety Climate Inventory (Brief NORSCI) – Psychometric properties and relationships with shift work, sleep, and health. *Safety Science*, *83*, 23-30. https://doi.org/https://doi.org/10.1016/j.ssci.2015.11.004

Paech, G. M., Jay, S. M., Lamond, N., Roach, G. D., & Ferguson, S. A. (2010). The effects of different roster schedules on sleep in miners. *Appl Ergon*, *41*(4), 600-606. https://doi.org/10.1016/j.apergo.2009.12.017

Parkes, K. R. (2012). Shift schedules on North Sea oil/gas installations: A systematic review of their impact on performance, safety and health. *Safety Science*, *50*(7), 1636-1651. https://doi.org/https://doi.org/10.1016/j.ssci.2012.01.010

Paterson, J., Ferguson S., & Dawson D. (2020). *Fatigue.* In The Core Body of Knowledge for Generalist OHS Professionals. 2nd Ed. Tullamarine, VIC: Australian Institute of Health and Safety.

Peetz, D., & Murray, G. (2011). 'You Get Really Old, Really Quick': Involuntary Long Hours in the Mining Industry. *Journal of Industrial Relations*, *53*(1), 13-29. https://doi.org/10.1177/0022185610390294

Peetz, D., Murray, G., & Muurlink, O. (2012). *Work and Hours Amongst Mining and Energy Workers.* Centre for Work, Organisation and Wellbeing, Griffith University.

Pelders, J., Magweregwede, F., & Rupprecht, S. M. (2021). Optimization of shift cycles in the South African mining sector. *Journal of the South African Institute of Mining and Metallurgy*, *121*(121), 427-436. https://doi.org/10.17159/2411-9717/1428/2021

Pelders, J., & Nelson, G. (2019). Contributors to fatigue at a platinum smelter in South Africa. *Journal of the Southern African Institute of Mining and Metallurgy*, *119*. https://doi.org/10.17159/2411-9717/2019/v119n3a11

Perring, A., Pham, K., Snow, S., & Buys, L. (2014). Investigation into the effect of infrastructure on fly-in fly-out mining workers. *Aust J Rural Health*, *22*(6), 323-327. https://doi.org/10.1111/ajr.12117

Pylkkönen, M., Tolvanen, A., Hublin, C., Kaartinen, J., Karhula, K., Puttonen, S., Sihvola, M., & Sallinen, M. (2018). Effects of alertness management training on sleepiness among long-haul truck drivers: A randomized controlled trial. *Accid Anal Prev*, *121*, 301-313. https://doi.org/10.1016/j.aap.2018.05.008

Roach. G., Dawson, D., & Sargent, C. (2022). *Assessing the Impact of Consecutive Night Shifts on Night-time Alertness, Daytime Sleep and Timing of the Circadian System* (ACARP Project C29021).

Rogers, N. L., & Whitwell, B. G. (2009). Fatigue and commuting in mine shiftworkers [Conference Abstract]. *Sleep*, *32*, A148-A149. https://www.embase.com/search/results?subaction=viewrecord&id=L70106624&from=export

Rosa, R. R., Härmä, M., Pulli, K., Mulder, M., & Näsman, O. (1996). Rescheduling a three shift system at a steel rolling mill: effects of a one hour delay of shift starting times on sleep and alertness in younger and older workers. *Occup Environ Med*, *53*(10), 677-685. https://doi.org/10.1136/oem.53.10.677

Sadeghniiat-Haghighi, K., Yazdi, Z., Jahanihashemi, H., & Aminian, O. (2011). The effect of bright light on sleepiness among rapid-rotating 12-hour shift workers. *Scand J Work Environ Health*, *37*(1), 77-79. https://doi.org/10.5271/sjweh.3086

Sun, E. (2017, July). The fuzzy neural network based haul truck driver fatigue detection in surface mining. In *2017 13th International Conference on Natural Computation, Fuzzy Systems and Knowledge Discovery (ICNC-FSKD)* (pp. 1522-1526). IEEE.

Sun, X., Zhang, L., Zhang, C., Liu, J., & Ge, H. (2020). The status of job burnout and its influence on the working ability of copper-nickel miners in Xinjiang, China. *BMC Public Health*, *20*(1), 305. https://doi.org/10.1186/s12889-020-8245-4

Waage, S., Moen, B. E., Pallesen, S., Eriksen, H. R., Ursin, H., Åkerstedt, T., & Bjorvatn, B. (2009). Shift work disorder among oil rig workers in the North Sea. *Sleep*, *32*(4), 558-565. https://doi.org/10.1093/sleep/32.4.558

Waage, S., Pallesen, S., Moen, B., & Bjorvatn, B. (2012). Sleep and Health in Oil Rig Workers - Before and After a Two Week Work Period Offshore. *Industrial health*, *51*. https://doi.org/10.2486/indhealth.2012-0091

Wilson, L. (2013). Case study: Utilising bio mathematical models for managing fatigue risk in a mining company [Conference Abstract]. *Sleep and Biological Rhythms*, *11*, 5. https://doi.org/10.1111/sbr.12028

Wu, H. W., Gillies, A. D. S., & Explorat, I. (1997). The development of a personal response heat stress meter calibrated to the physiology of the range of employees within the mine workplace. *6th International Mine Ventilation Congress (IMVC)*, 255-261. <Go to ISI>://WOS:A1997BH96V00040

Zhang, M., Kecojevic, V., & Komljenovic, D. (2014). Investigation of haul truck-related fatal accidents in surface mining using fault tree analysis. *Safety science*, *65*, 106-117.

Zhou, Z., Zhang, Y., Sang, L., Shen, J., & Lian, Y. (2022). Association between sleep disorders and shift work: a prospective cohort study in the Chinese petroleum industry. *Int J Occup Saf Ergon*, *28*(2), 751-757. https://doi.org/10.1080/10803548.2020.1826706

**Part 2**

Akbar, D., Kinnear, S., Chhetri, P., & Smith, P. (2018). Assessing Mining Impacts On Road Travel Conditions In An Intensive Coal Mining Region In Australia: A Case Study Of The Northern Bowen Basin. *Australasian Journal of Regional Studies, 24*(1), 35-61. //WOS:000433213400003

Asare, B. Y., Kwasnicka, D., Powell, D., & Robinson, S. (2021). Health and well-being of rotation workers in the mining, offshore oil and gas, and construction industry: a systematic review. *BMJ Glob Health, 6*(7). https://doi.org/10.1136/bmjgh-2021-005112

Asare, B. Y., Robinson, S., Powell, D., & Kwasnicka, D. (2022). Health and related behaviours of fly-in fly-out workers in the mining industry in Australia: a cross-sectional study. *Int Arch Occup Environ Health*, 1-16. https://doi.org/10.1007/s00420-022-01908-x

Baker, A., Heiler, K., & Ferguson, S. A. (2001). The effects of a roster schedule change from 8- to 12-hour shifts on health and safety in a mining operation. *J Hum Ergol (Tokyo), 30*(1-2), 65-70.

Baulk, S. D., Fletcher, A., Kandelaars, K. J., Dawson, D., & Roach, G. D. (2009). A field study of sleep and fatigue in a regular rotating 12-h shift system. *Appl Ergon, 40*(4), 694-698. https://doi.org/10.1016/j.apergo.2008.06.003

Bazazan, A., Rasoulzadeh, Y., Dianat, I., Safaiyan, A., & Mombeini, Z. (2019). Occupational fatigue and mental health complaints among 8-hour shift workers of petrochemical industries in Iran. *Work, 62*(2), 309-317. https://doi.org/10.3233/wor-192865

Berthelsen, M., Pallesen, S., Bjorvatn, B., & Knardahl, S. (2015). Shift schedules, work factors, and mental health among onshore and offshore workers in the Norwegian petroleum industry. *Ind Health, 53*(3), 280-292. https://doi.org/10.2486/indhealth.2014-0186

Bhattacherjee, A., Bertrand, J. P., Meyer, J. P., Benamghar, L., Otero Sierra, C., Michaely, J. P., Ghosh, A. K., d'Houtaud, A., Mur, J. M., & Chau, N. (2007). Relationships of physical job tasks and living conditions with occupational injuries in coal miners. *Ind Health, 45*(2), 352-358. https://doi.org/10.2486/indhealth.45.352

Bhuanantanondh, P., Bandidcharoenlert, P., Jalayondeja, W., Jalayondeja, C., & Mekhora, K. (2021). Fatigue assessment among onshore oil rig shift workers in Thailand. *International Journal of Industrial Ergonomics, 83*. https://doi.org/10.1016/j.ergon.2021.103137

Bjorvatn, B., Stangenes, K., Oyane, N., Forberg, K., Lowden, A., Holsten, F., & Akerstedt, T. (2006). Subjective and objective measures of adaptation and readaptation to night work on an oil rig in the North Sea. *Sleep, 29*(6), 821-829. https://doi.org/10.1093/sleep/29.6.821

Bowers, J., Lo, J., Miller, P., Mawren, D., & Jones, B. (2018). Psychological distress in remote mining and construction workers in Australia. *Med J Aust, 208*(9), 391-397. https://doi.org/10.5694/mja17.00950

Brake, D. J., & Bates, G. P. (2001). Fatigue in industrial workers under thermal stress on extended shift lengths. *Occup Med (Lond), 51*(7), 456-463. https://doi.org/10.1093/occmed/51.7.456

Brown. (1994). Driver fatigue. *Human Factors*. 298-314.

Chen, Z. B., Qiao, G. Z., & Zeng, J. C. (2019). Study on the Relationship between Worker States and Unsafe Behaviours in Coal Mine Accidents Based on a Bayesian Networks Model. *Sustainability, 11*(18). https://doi.org/10.3390/su11185021

Chimamise, C., Gombe, N. T., Tshimanga, M., Chadambuka, A., Shambira, G., & Chimusoro, A. (2013). Factors associated with severe occupational injuries at mining company in Zimbabwe, 2010: a cross-sectional study. *Pan Afr Med J, 14*, 5. https://doi.org/10.11604/pamj.2013.14.5.1148

Cliff, D. (2005). Establishment of hours of work risk factors relevant to coal mining. ACARP report.

Cui, Y., Tian, S. S., Qiao, N., Wang, C., Wang, T., Huang, J. J., Sun, C. M., Liang, J., & Liu, X. M. (2015). Associations of Individual-Related and Job-Related Risk Factors with Nonfatal Occupational Injury in the Coal Workers of Shanxi Province: A Cross-Sectional Study. *PLoS One, 10*(7), e0134367. https://doi.org/10.1371/journal.pone.0134367

de Arruda, A. F., & Gontijo, L. M. (2012). Application of ergonomics principles in underground mines through the Occupational Safety and Health Management System--OSHMS OHSAS 18.001:2007. *Work, 41 Suppl 1*, 4460-4467. https://doi.org/10.3233/wor-2012-0119-4460

De, S., Almberg, K. S., Cohen, R. A., & Friedman, L. S. (2020). Injuries during the first hour at work in the U.S. mining industry. *Am J Ind Med, 63*(12), 1124-1133. https://doi.org/10.1002/ajim.23186

Djamalus, H., Utomo, B., Djaja, I. M., & Nasri, S. M. (2021). Mental Fatigue and Its Associated Factors among Coal Mining Workers after One Year of the COVID-19 Pandemic in Indonesia. *Kesmas: National Public Health Journal, 16*(4), 228-233. https://doi.org/10.21109/kesmas.v16i4.5154

Donoghue, A. M., Frisch, N., & Olney, D. (2014). Bauxite mining and alumina refining: process description and occupational health risks. *J Occup Environ Med, 56*(5 Suppl), S12-17. https://doi.org/10.1097/jom.0000000000000001

Donoghue, A. M., Sinclair, M. J., & Bates, G. P. (2000). Heat exhaustion in a deep underground metalliferous mine. *Occup Environ Med, 57*(3), 165-174. https://doi.org/10.1136/oem.57.3.165

Duchon, J. C., & Keran, C. M. (1990). Relationships among shiftworker eating habits, eating satisfaction, and self-reported health in a population of US miners. *Work and Stress, 4*(2), 111-120. https://www.embase.com/search/results?subaction=viewrecord&id=L20369406&from=export

Duchon, J. C., Keran, C. M., & Smith, T. J. (1994). Extended workdays in an underground mine: a work performance analysis. *Hum Factors, 36*(2), 258-268. https://doi.org/10.1177/001872089403600207

Duchon, J. C., Smith, T. J., Keran, C. M., & Koehler, E. J. (1997, 1997/07/01/). Psychophysiological manifestations of performance during work on extended workshifts. *International Journal of Industrial Ergonomics, 20*(1), 39-49. https://doi.org/https://doi.org/10.1016/S0169-8141(96)00030-3

Ebert, A., & Strehlow, K. (2017). Does on-site chaplaincy enhance the health and well being of fly-in, fly-out (FIFO) personnel? *Health Promot J Austr, 28*(2), 118-122. https://doi.org/10.1071/he16019

Eiter, B. M., Steiner, L., & Kelhart, A. (2014). Application of fatigue management systems: small mines and low technology solutions. *Min Eng, 66*(4), 69-75. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4539295/pdf/nihms707260.pdf

Ferguson, S. A., Baker, A. A., Lamond, N., Kennaway, D. J., & Dawson, D. (2010). Sleep in a live-in mining operation: the influence of start times and restricted non-work activities. *Appl Ergon, 42*(1), 71-75. https://doi.org/10.1016/j.apergo.2010.05.001

Fido, A., & Ghali, A. (2008). Detrimental effects of variable work shifts on quality of sleep, general health and work performance. *Med Princ Pract, 17*(6), 453-457. https://doi.org/10.1159/000151566

Fletcher, A. (2010). Staying safe in the jungles of Borneo: five studies of fatigue and cultural issues in remote mining projects. *Ind Health, 48*(4), 406-415. https://doi.org/10.2486/indhealth.mssw-04

Folkard S, Lombardi DA, Tucker PT. Shiftwork: safety, sleepiness and sleep. Ind Health. 2005 Jan;43(1):20-3. doi: 10.2486/indhealth.43.20.

Fossum, I. N., Bjorvatn, B., Waage, S., & Pallesen, S. (2013). Effects of shift and night work in the offshore petroleum industry: a systematic review. *Ind Health, 51*(5), 530-544. https://doi.org/10.2486/indhealth.2013-0054

Friedman, L. S., Almberg, K. S., & Cohen, R. A. (2019). Injuries associated with long working hours among employees in the US mining industry: risk factors and adverse outcomes. *Occupational and Environmental Medicine, 76*(6), 389. https://doi.org/10.1136/oemed-2018-105558

Gao, X., Ma, K. L., Wang, H., Gao, Q., Lei, L. J., & Wang, T. (2019). Association of sleep quality with job burnout among Chinese coal mine staff: a propensity score weighting analysis. *Sci Rep, 9*(1), 8737. https://doi.org/10.1038/s41598-019-45329-2

Hanoa, R., Baste, V., Kooij, A., Sommervold, L., & Moen, B. E. (2011). No difference in self reported health among coalminers in two different shift schedules at Spitsbergen, Norway, a two years follow-up. *Ind Health, 49*(5), 652-657. https://doi.org/10.2486/indhealth.ms1280

Harris, A., Waage, S., Ursin, H., Hansen, A. M., Bjorvatn, B., & Eriksen, H. R. (2010). Cortisol, reaction time test and health among offshore shift workers. *Psychoneuroendocrinology, 35*(9), 1339-1347. https://doi.org/10.1016/j.psyneuen.2010.03.006

Hystad, S. W., Saus, E. R., Sætrevik, B., & Eid, J. (2013). Fatigue in seafarers working in the offshore oil and gas re-supply industry: effects of safety climate, psychosocial work environment and shift arrangement. *Int Marit Health, 64*(2), 72-79. https://journals.viamedica.pl/international_maritime_health/article/download/34688/25360

James, C., Tynan, R., Roach, D., Leigh, L., Oldmeadow, C., Rahman, M., & Kelly, B. (2018). Correlates of psychological distress among workers in the mining industry in remote Australia: Evidence from a multi-site cross-sectional survey. *PLoS One, 13*(12), e0209377. https://doi.org/10.1371/journal.pone.0209377

Jia, A., Guo, X., & Tian, S. (2022). Experimental study on the influence of mental fatigue on risk decision-making of miners. *Sci Rep, 12*(1), 11902. https://doi.org/10.1038/s41598-022-14045-9

Jiang, Y., Li, P., Zhong, L., Liu, B., Gao, X., Ning, L., Lian, Y., & Liu, J. (2021). The influence of changes in work stressors and coping resources on sleep disturbances:

evidence from the OHSPIW cohort study. *Sleep, 44*(8), zsab039. https://doi.org/10.1093/sleep/zsab039

Jiang, Y., Li, P., Zhong, L., Liu, B., Gao, X., Ning, L., Lian, Y., & Liu, J. (2021). The influence of changes in work stressors and coping resources on sleep disturbances: evidence from the OHSPIW cohort study. *Sleep, 44*(8). https://doi.org/10.1093/sleep/zsab039

Langdon, R. R., Biggs, H. C., & Rowland, B. (2016). Australian fly-in, fly-out operations: Impacts on communities, safety, workers and their families. *Work, 55*(2), 413-427. https://doi.org/10.3233/wor-162412

Le, A. B., Balogun, A. O., & Smith, T. D. (2022). Long Work Hours, Overtime, and Worker Health Impairment: A Cross-Sectional Study among Stone, Sand, and Gravel Mine Workers. *International Journal of Environmental Research and Public Health, 19*(13). https://doi.org/10.3390/ijerph19137740

Legault, G. (2011). Sleep and Heat Related Changes in the Cognitive Performance of Underground Miners: A Possible Health and Safety Concern. *Minerals, 1*(1), 49-72. https://doi.org/10.3390/min1010049

Legault, G., Clement, A., Kenny, G. P., Hardcastle, S., & Keller, N. (2017). Cognitive consequences of sleep deprivation, shiftwork, and heat exposure for underground miners. *Appl Ergon, 58*, 144-150. https://doi.org/10.1016/j.apergo.2016.06.007

Li, J., Qin, Y., Yang, L., Wang, Z., Han, K., & Guan, C. (2021). A simulation experiment study to examine the effects of noise on miners' safety behavior in underground coal mines. *BMC Public Health, 21*(1), 324. https://doi.org/10.1186/s12889-021-10354-2

Ljoså, C. H., & Lau, B. (2009). Shiftwork in the Norwegian petroleum industry: overcoming difficulties with family and social life - a cross sectional study. *J Occup Med Toxicol, 4*, 22. https://doi.org/10.1186/1745-6673-4-22

Loudoun, R. J., Muurlink, O., Peetz, D., & Murray, G. (2014). Does age affect the relationship between control at work and sleep disturbance for shift workers? *Chronobiol Int, 31*(10), 1190-1200. https://doi.org/10.3109/07420528.2014.957307

Lovell, J., & Critchley, J. (2010). Women living in a remote Australian mining community: exploring their psychological well-being. *Aust J Rural Health, 18*(3), 125-130. https://doi.org/10.1111/j.1440-1584.2010.01143.x

Maisey, G., Cattani, M., Devine, A., Lo, J., & Dunican, I. C. (2020). The Sleep of Shift Workers in a Remote Mining Operation: Methodology for a Randomized Control Trial to Determine Evidence-Based Interventions. *Front Neurosci, 14*, 579668. https://doi.org/10.3389/fnins.2020.579668

Maisey, G., Cattani, M., Devine, A., Lo, J., Fu, S. C., & Dunican, I. C. (2022). Digging for data: How sleep is losing out to roster design, sleep disorders, and lifestyle factors. *Appl Ergon, 99*, 103617. https://doi.org/10.1016/j.apergo.2021.103617

Marot, L. P., Rosa, D. E., Lopes, T., Moreno, C. R. C., & Crispim, C. A. (2021). Eating Duration throughout a Rotating Shift Schedule: A Case Study. *J Am Coll Nutr, 40*(7), 624-631. https://doi.org/10.1080/07315724.2020.1814899

Mathisen, G. E., & Bergh, L. I. V. (2016). Action errors and rule violations at offshore oil rigs: The role of engagement, emotional exhaustion and health complaints. *Safety Science, 85*, 130-138. https://doi.org/10.1016/j.ssci.2016.01.008

McLean, K. N. (2012). Mental health and well-being in resident mine workers: out of the fly-in fly-out box. *Aust J Rural Health, 20*(3), 126-130. https://doi.org/10.1111/j.1440-1584.2012.01267.x

Merkus, S. L., Huysmans, M. A., Holte, K. A., van Mechelen, W., & van der Beek, A. J. (2017). An active transition from offshore work to family life: Activities that may impact recovery. *Work, 58*(3), 371-381. https://doi.org/10.3233/wor-172631

Muller, R., Carter, A., & Williamson, A. (2008). Epidemiological diagnosis of occupational fatigue in a fly-in fly-out operation of the mineral industry. *Ann Occup Hyg, 52*(1), 63-72. https://doi.org/10.1093/annhyg/mem058

Ning, L., Shi, L., Tao, N., Li, R., Jiang, T., & Liu, J. (2020). Effects of Occupational Stress and Circadian CLOCK Gene Polymorphism on Sleep Quality of Oil Workers in Xinjiang, China. *Med Sci Monit, 26*, e924202. https://doi.org/10.12659/msm.924202

Nunfam, V. F., Adusei-Asante, K., Van Etten, E. J., Frimpong, K., & Oosthuizen, J. (2021). Estimating the magnitude and risk associated with heat exposure among Ghanaian mining workers. *Int J Biometeorol, 65*(12), 2059-2075. https://doi.org/10.1007/s00484-021-02164-3

Ogiński, A., Ogińska, H., Pokorski, J., Kmita, W., & Goździela, R. (2000). Internal and external factors influencing time-related injury risk in continuous shift work. *Int J Occup Saf Ergon, 6*(3), 405-421. https://doi.org/10.1080/10803548.2000.11076464

Paech, G. M., Jay, S. M., Lamond, N., Roach, G. D., & Ferguson, S. A. (2010). The effects of different roster schedules on sleep in miners. *Appl Ergon, 41*(4), 600-606. https://doi.org/10.1016/j.apergo.2009.12.017

Parkes, K. R. (2012). Shift schedules on North Sea oil/gas installations: A systematic review of their impact on performance, safety and health. *Safety Science, 50*(7), 1636-1651. https://doi.org/10.1016/j.ssci.2012.01.010

Parkes, K. R. (2015). Sleep patterns of offshore day-workers in relation to overtime work and age. *Appl Ergon, 48*, 232-239. https://doi.org/10.1016/j.apergo.2014.12.004

Parkes, K. R. (2016). Age and work environment characteristics in relation to sleep: Additive, interactive and curvilinear effects. *Appl Ergon, 54*, 41-50. https://doi.org/10.1016/j.apergo.2015.11.009

Peetz, D., & Murray, G. (2011). 'You Get Really Old, Really Quick': Involuntary Long Hours in the Mining Industry. *Journal of Industrial Relations, 53*(1), 13-29. https://doi.org/10.1177/0022185610390294

Pelders, J., Magweregwede, F., & Rupprecht, S. M. (2021). Optimization of shift cycles in the South African mining sector. *Journal of the Southern African Institute of Mining and Metallurgy, 121*(8), 426-435. https://doi.org/10.17159/2411-9717/1428/2021

Perring, A., Pham, K., Snow, S., & Buys, L. (2014). Investigation into the effect of infrastructure on fly-in fly-out mining workers. *Aust J Rural Health, 22*(6), 323-327. https://doi.org/10.1111/ajr.12117

Pirotta, J. (2009). An Exploration of the Experiences of Women Who FIFO. *Australian Community Psychologist, 21*(2), 37-51. <Go to ISI>://WOS:000214814200004

Pizarro-Montaner, C., Cancino-Lopez, J., Ponce-Reyes, A., & Flores-Opazo, M. (2020). Interplay between rotational work shift and high altitude-related chronic intermittent hypobaric hypoxia on cardiovascular health and sleep quality in Chilean miners. *Ergonomics, 63*(10), 1281-1292. https://doi.org/10.1080/00140139.2020.1774079

Robinson, K., Peetz, D., Murray, G., Griffin, S., & Muurlink, O. (2017). Relationships between children's behaviour and parents' work within families of mining and energy workers. *Journal of Sociology, 53*(3), 557-576. https://doi.org/10.1177/1440783316674357

Rosa, D. E., Marot, L. P., de Mello, M. T., Narcisoz, F. V., Goncalves, B. D. B., Marqueze, E. C., & Crispim, C. A. (2019). Shift rotation, circadian misalignment and excessive body weight influence psychomotor performance: a prospective and observational study under real life conditions. *Scientific Reports, 9*. https://doi.org/10.1038/s41598-019-55114-w

Ross, J. K. (2009). Offshore industry shift work--health and social considerations. *Occup Med (Lond), 59*(5), 310-315. https://doi.org/10.1093/occmed/kqp074

Roy, S., Mishra, D. P., Bhattacharjee, R. M., & Agrawal, H. (2022). Heat Stress in Underground Mines and its Control Measures: A Systematic Literature Review and Retrospective Analysis. *Mining Metallurgy & Exploration, 39*(2), 357-383. https://doi.org/10.1007/s42461-021-00532-6

Ryan, F., Otto, B., Khan, A., & Johnston, V. (2017). A cross-sectional study of work-related and lifestyle factors associated with the health of Australian long distance commute and residential miners. *European Journal of Physiotherapy, 19*, 25-26. https://doi.org/10.1080/21679169.2017.1381324

Sadeghniiat-Haghighi, K., Mehrabinejad, M.-M., Hajighaderi, A., Najafi, A., Rahimi-Golkhandan, A., & Zahabi, A. (2021). Shift Work Disorder, Insomnia, and Depression among Offshore Oil Rig Workers. *Iranian Journal of Psychiatry, 16*(2), 162-167. https://search.ebscohost.com/login.aspx?direct=true&db=ccm&AN=149674168&site=ehost-live https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8233558/pdf/IJPS-16-162.pdf

Saksvik, I. B., Bjorvatn, B., Harvey, A. G., Waage, S., Harris, A., & Pallesen, S. (2011). Adaptation and readaptation to different shift work schedules measured with sleep diary and actigraphy. *Journal of Occupational Health Psychology, 16*(3), 331-344. https://doi.org/10.1037/a0022770

Sekkay, F., Imbeau, D., Dubé, P. A., Chinniah, Y., de Marcellis-Warin, N., Beauregard, N., & Trépanier, M. (2020). Assessment of physical work demand of short distance industrial gas delivery truck drivers. *Appl Ergon, 89*, 103222. https://doi.org/10.1016/j.apergo.2020.103222

Shaikh, S. A., & Krishnan, P. (2012). A Framework for Analysing Driver Interactions with Semi-Autonomous Vehicles. *Electronic Proceedings in Theoretical Computer Science*(105), 85-99. https://doi.org/10.4204/eptcs.105.7

Sun, X., Zhang, L., Zhang, C., Liu, J., & Ge, H. (2020). The status of job burnout and its influence on the working ability of copper-nickel miners in Xinjiang, China. *BMC Public Health, 20*(1), 305. https://doi.org/10.1186/s12889-020-8245-4

Thirumala, V., Verma, T., Gupta, S., Ieee, & Ieee, I. (2017). Injury Analysis of Mine Workers: A Case Study. *IEEE International Conference on Industrial Engineering and Engineering Management (IEEE IEEM)*, 269-273. //WOS:000428267800056

Waage, S., Bente, E. M., Pallesen, S., Hege, R. E., Holger, U., Akerstedt, T., & Bjorvatn, B. (2009). Shift Work Disorder Among Oil Rig Workers in the North Sea. *Sleep, 32*(4), 558-565. https://doi.org/10.1093/sleep/32.4.558

Waage, S., Pallesen, S., Moen, B. E., & Bjorvatn, B. (2010). Shift work and age in petroleum offshore industry. *Int Marit Health, 62*(4), 251-257.

Waage, S., Pallesen, S., Moen, B. E., & Bjorvatn, B. (2013). Sleep and health in oil rig workers--before and after a two week work period offshore. *Ind Health, 51*(2), 172-179. https://doi.org/10.2486/indhealth.2012-0091

Widanarko, B., Legg, S., Devereux, J., & Stevenson, M. (2015). Interaction between physical and psychosocial work risk factors for low back symptoms and its consequences amongst Indonesian coal mining workers. *Appl Ergon, 46 Pt A*, 158-167. https://doi.org/10.1016/j.apergo.2014.07.016

Wong, I. and Swenson, N. (2022) Approaches to managing work-related fatigue to meet the needs of American workers and employers, *American Journal of Industrial Medicine*, 65, 827-831.

Wu, H. W., Gillies, A. D. S., Us Dept Labor, M. S. & Explorat, I. (1997). The development of a personal response heat stress meter calibrated to the physiology of the range of employees within the mine workplace. *6th International Mine Ventilation Congress (IMVC)*, 255-261. //WOS:A1997BH96V00040

Yeoman, K., Sussell, A., Retzer, K., & Poplin, G. (2020). Health Risk Factors Among Miners, Oil and Gas Extraction Workers, Other Manual Labor Workers, and Nonmanual Labor Workers, BRFSS 2013-2017, 32 States. *Workplace Health Saf, 68*(8), 391-401. https://doi.org/10.1177/2165079920909136

Yi, T., Dong, Y., & Li, J. Z. (2021). Influence of job insecurity on coal miners' safety performance: the role of emotional exhaustion. *Chinese Management Studies*. https://doi.org/10.1108/cms-10-2020-0455

Yu, M., & Li, J. (2020). Work-family conflict and mental health among Chinese underground coal miners: the moderating role of psychological capital. *Psychol Health Med, 25*(1), 1-9. https://doi.org/10.1080/13548506.2019.1595686

Zare, R., Choobineh, A., & Keshavarzi, S. (2017). Association of Amplitude and Stability of Circadian Rhythm, Sleep Quality, and Occupational Stress with Sickness Absence among a Gas Company Employees-A Cross Sectional Study from Iran. *Saf Health Work, 8*(3), 276-281. https://doi.org/10.1016/j.shaw.2016.09.007

Zhao, X. C., Han, K. Y., Gao, Y. Y., Li, N., Wang, L., Yu, L. L., Song, M., & Wang, X. Y. (2021). Effects of shift work on sleep and cognitive function among male miners. *Psychiatry Res, 297*, 113716. https://doi.org/10.1016/j.psychres.2021.113716

Zhou, Z., Zhang, Y., Sang, L., Shen, J., & Lian, Y. (2022). Association between sleep disorders and shift work: a prospective cohort study in the Chinese petroleum industry. *Int J Occup Saf Ergon, 28*(2), 751-757. https://doi.org/10.1080/10803548.2020.1826706

Contact details

Project Manager: Professor Tim Horberry.

Technical Reviewer: Professor David Cliff.

Authors:  T. Horberry, J. Harris, K. Way, A. Hill, N. Lim, P. Dodshon, J. Lee and D. Cliff

Minerals Industry Safety and Health Centre, CSRM & School of Psychology
T    +61 07 3346 4066
E    t.horberry@uq.edu.au
W   smi.uq.edu.au

CRICOS Provider Number 00025B

Appendix A:

**CODES OF PRACTICE**

| | Extractive | | General H&S | | Transport | Aviation |
|---|---|---|---|---|---|---|
| | WA | NSW | National | | National | National |
| | **WHCOP** | **SMS in Mines** | **Managing Psych Hazards COP** | **How to Manage WHS Risks COP** | **Master Code** | **Civil Aviation Instrument 2019** |
| Obligations | The employer's general 'duty of care' obligations for safety and health under the OSH Act and the MSI Act include: • providing a workplace and safe system of work so employees are not exposed to hazards; • providing employees with information, instruction, training and supervision to enable them to work in a safe manner; and • consulting and cooperating with employees and safety and health representatives (where they exist) in matters related to safety and health at work. Employees also have obligations under the OSH Act and the MSI Act. They must take reasonable care to ensure their own safety and health at work and that of others affected by their work and report any situations that may be hazardous. Their duty for safety and health at the workplace is complementary to the employer's duty and they need to receive adequate information, instruction, training and supervision to fulfil it. | The WHS Act requires all persons conducting a business or undertaking (PCBU), including the mine holder and the mine operator, to ensure, so far as is reasonably practicable2, the health and safety of workers and that the health and safety of other people is not put at risk from work carried out as part of the business or undertaking. This means eliminating or minimising risks to health and safety, so far as is reasonably practicable. | A PCBU must ensure, so far as is reasonably practicable, workers and other persons are not exposed to risks to their psychological or physical health and safety. A PCBU must eliminate psychosocial risks in the workplace, or if that is not reasonably practicable, minimise these risks so far as is reasonably practicable. Workers must take reasonable care for their own psychological and physical health and safety and to not adversely affect the health and safety of other persons. Workers must comply with reasonable health and safety instructions, as far as they are reasonably able, and cooperate with reasonable health and safety policies or procedures that have been notified to workers | A PCBU must eliminate risks in the workplace, or if that is not reasonably practicable, minimise the risks so far as is reasonably practicable. Workers have a duty to take reasonable care for their own health and safety and to not adversely affect the health and safety of other persons. Workers must comply with reasonable instructions, as far as they are reasonably able, and cooperate with reasonable health and safety policies or procedures that have been notified to workers. If personal protective equipment (PPE) is provided by the business or undertaking, the worker must so far as they are reasonably able, use or wear it in accordance with the information and instruction and training provided. | The HVNL imposes a positive duty on all CoR parties to ensure the safety of their transport activities (section 26C(1)of the HVNL). They must do this in at least two ways: by eliminating or minimising public risks; and by ensuring their conduct doesn't cause or encourage a driver or another person, directly or indirectly, to breach the HVNL. A CoR party's duty is to ensure the safety of their transport activities 'so far as is reasonably practicable. | An AOC holder must set out in the operations manual its employees' responsibilities for operational fatigue management, and fatigue risk management.<br>Meals<br>14.5 Except for operations under Appendix 7 — Fatigue Risk Management System (FRMS), where an FCM's FDP is to exceed 5 hours, the AOC holder must provide the opportunity for the FCM to have access to adequate sustenance (a meal) during the first 5 hours and periodically after that meal, so that not more than 5 hours elapse between each meal.<br>Note For operations under Appendix 7, it is expected that the FRMS would provide the opportunity for FCMs to have access to adequate sustenance at appropriate intervals.<br>Records and reports<br>14.6 An AOC holder must maintain records (including relevant reports and documents) of the following:<br>(a) FCM rosters;<br>(b) actual duty periods;<br>(c) actual flight times of each FCM when acting in the capacity of a crew member;<br>Note Thus, the flight time record does not include time spent positioning.<br>(d) actual split-duty rest periods, standby periods and off-duty periods;<br>(e) any FDP that was extended under the relevant provision (if any) of the Appendix or FRMS which the AOC holder has chosen to comply with, including information about the extensions in such detail as enables the holder to comply with subparagraph 14.8 (a).<br>Note A record under subparagraph 14.6 (e) is not required where an FDP is reassigned under the relevant provision of the Appendix, unless the reassignment results in an FDP that exceeds the relevant limit set out in the AOC holder's operations manual.<br>14.7 Each record mentioned in paragraph 14.6, including copies of reports and documents, must be |
| Hazard Identification | Required as part of the three-step risk management process as required under The Occupational Safety and Health Regulations 1996 (the OSH Regulations) | Required as part of the four-step risk management process as required under the WHS (Mines) Regulation | Required as part of the four-step risk management process as required under the code of practice | Required as part of the four-step risk management process as required under the code of practice | Required as part of the four-step risk management process as required under the master code | |
| Risk Assessment | Required as part of the three-step risk management process as required under The Occupational Safety and Health Regulations 1996 (the OSH Regulations) | Required as part of the four-step risk management process as required under the WHS (Mines) Regulation | Required as part of the four-step risk management process as required under the code of practice | Required as part of the four-step risk management process as required under the code of practice | Required as part of the four-step risk management process as required under the master code | FRMS risk assessment procedures must be capable of determining the following:<br>(a) the probability of events occurring or circumstances arising that create a fatigue-related hazard;<br>(b) the potential severity of fatigue-related hazards;<br>(c) when the safety risks associated with paragraph (a) or (b) require mitigation.<br>4.6 For subclause 4.5, the FRMS risk assessment procedures must ensure that identified fatigue-related hazards are examined in relation to the following:<br>(a) the relevant operational context and procedures in which the identified fatigue-related hazard arose;<br>(b) the probability of the fatigue-related hazard arising in those circumstances;<br>(c) the possible consequences of the fatigue-related hazard in those circumstances;<br>(d) the effectiveness of existing safety procedures and controls. |
| Risk Control | Required as part of the three-step risk management process as required under The Occupational Safety and Health Regulations 1996 (the OSH Regulations) | Required as part of the four-step risk management process as required under the WHS (Mines) Regulation | Required as part of the four-step risk management process as required under the code of practice | Required as part of the four-step risk management process as required under the code of practice | Required as part of the four-step risk management process as required under the master code | FRMS risk mitigation procedures for each fatigue-related hazards must be capable of:<br>(a) selecting appropriate mitigation strategies for the hazard; and<br>(b) implementing the selected mitigation strategies; and<br>(c) monitoring the implementation and effectiveness of the strategies. |
| Reviewing Controls | Constantly monitor and review the working hours control measures to ensure they continue to prevent or control exposure to hazards or hazardous work practices. | Required as part of the four-step risk management process as required under the WHS (Mines) Regulation | Required as part of the four-step risk management process as required under the code of practice | Required as part of the four-step risk management process as required under the code of practice | Required as part of the four-step risk management process as required under the master code | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Information, Instruction, Training and Supervision | The OSH Act, MSI Act and MSI Regulations require training on safe work procedures to be provided. Employers must provide an appropriate level of supervision relevant to the assessed level of risk. | The mine operator has a duty to ensure a range of information, training and instruction is provided to workers, which could be achieved by having an initial induction and orientation for workers, stipulating work requirements or procedures, training and instruction in relation to specific risk-control measures and refresher training as required under the WHS (Mines) Regulation. Supervision is essential to check that work instructions and procedures are followed and tasks are completed as required. Arrangements may be for direct or indirect supervision or a mix of levels. What is appropriate to the mine and the number of supervisors required will depend on factors such as remote work and level of risk as required under the WHS (Mines) Regulation. | As you are planning to implement control measures, you must consider what information, training, instruction or supervision is required to ensure the control measures are effective.<br>Training must be suitable and adequate, having regard to:<br>- the nature of the work to be carried out<br>- the associated psychosocial hazards and risks, and<br>- the control measures to be implemented.<br>Training should require workers to demonstrate they are competent in performing the task. It is not sufficient to simply tell a worker about the procedure and ask them to acknowledge they understand and can perform it. Training may include formal training courses, in-house training or on the job training.<br>For example, if supervisors and managers have a role in implementing workplace policies on addressing harmful behaviours, you must provide them with any training necessary to ensure safety. This may include training, so they know what to do if they witness, experience or have a worker approach them about violence and aggression, bullying or sexual harassment at work or know who to seek guidance from if they have questions.<br>Information, training and instruction must be provided in a form all workers can understand, for example training may need to be provided in other languages. Information and instruction may also need to be provided to others who enter the workplace, such as customers or visitors. | Training, instruction and information<br>Train your workers in the work procedure to ensure that they are able to perform the task safely. Training must cover the nature of the work, the associated risks and the control measures to be implemented.<br>Training should require workers to demonstrate that they are competent in performing the task according to the procedure. It is insufficient to simply give a worker the procedure and ask them to acknowledge that they understand and are able to perform it. Training, instruction and information must be provided in a form that can be understood by all workers.<br>Information and instruction may also need to be provided to others who enter the workplace, such as customers or visitors.<br>Supervision<br>The level of supervision required will depend on the level of risk and the experience of the workers involved. High levels of supervision are necessary where inexperienced workers are expected to follow new procedures or carry out difficult and critical tasks. | The primary WHS Law has a duty to provide any information, training, instruction or supervision that is necessary to protect all people from risks to their health and safety arising from work carried out (section 19 of the WHS Act). Although this is not a specific requirement of the HVNL, it may be an important part of how duties under the HVNL are met. | |
| Documentation | | The mine operator must develop procedures for the management of all the records needed to comply with the WHS Act and WHS Regulations | You should record your risk management process and the outcomes, including your consultation with workers. This allows you to demonstrate you have met your work health and safety duties and will assist you when you need to monitor or review the hazards you have identified and controls you have put in place | Keeping records of the risk management process demonstrates what you have done to comply with the WHS Act and WHS Regulations. It also helps when undertaking subsequent risk management activities, including reviewing your control measures. | It is important to document the risk management process to demonstrate what you have done to manage the safety of your transport activities and to comply with the HVNL. A documented risk management process also helps when monitoring controls and reviewing risks so that you can recall what you have done and why, and to keep a record of any changes. | The AOC holder must have an FRMS policy:<br>(a) referring to all elements of the FRMS mentioned in subclause 1.2; and<br>(b) if the AOC holder has an SMS — which integrates the FRMS with the SMS.<br>2.2 The policy must require that all operations to which the FRMS applies be clearly defined in the operations manual.<br>2.3 The policy must:<br>(a) make it clear that while primary responsibility for the FRMS lies with the AOC holder, its effective implementation requires shared responsibility by management, FCMs, and other relevant personnel; and<br>(b) clearly indicate the safety objectives of the FRMS; and<br>(c) be approved in writing by the Chief Executive Officer; and<br>(d) be accessible to all relevant areas and levels of the organisation in a way that indicates the AOC holder's specific endorsement of the policy; and<br>(e) declare management commitment to:<br>(i) effective safety reporting; and<br>(ii) provision of adequate resources for the FRMS; and<br>(iii) continuous improvement of the FRMS; and<br>(f) require that clear lines of accountability are identified for management, FCMs, and all other relevant personnel; and<br>(g) require periodic reviews to ensure the policy remains relevant and appropriate.<br>2.4 The policy must:<br>(a) be in a written statement; and<br>(b) require that each other element of the FRMS mentioned in subclause 1.2 be described in a written statement.<br>2.5 In addition to the requirements under subclause 2.4, and the relevant limits and procedures contained in the operations manual in accordance with this CAO, the FRMS |

## GUIDANCE NOTES

| | QLD | NSW | GH&S | Transport |
|---|---|---|---|---|
| **Fatigue Risk Management Processes** | **QGN16** | **FM Guidance** | **Guidefor managing risk of fatigue** | **NTC Guidelines** |
| Recognition of Fatigue as a hazard | Yes. There is a direct link between fatigue and increased risk of being involved in an incident or accident. | Yes. Unmanaged fatigue related impairment is both an organisational and individual hazard. | Yes. Fatigue can adversely affect safety at the workplace. Fatigue reduces alertness which may lead to errors and an increase in incidents and injuries | Fatigue is more than falling asleep at the wheel. Fatigue describes the feeling of being tired, drained or exhausted. It causes poor judgment, impaired coordination and slower reactions, and impacts on how well you work. It builds up, leading to a progressive loss of alertness that ultimately ends in sleep and is a major contributing factor in many road crashes. |
| Organisational Obligations | Operators and SSEs hold the fundamental obligation for managing the risks associated with fatigue. | The PCBU (s19 WHS Act 2011) has the primary duty to ensure the health and safety of workers. | The PCBU has the primary duty to ensure, so far as is reasonably practicable, workers and other persons are not exposed to health and safety risks arising from the business or undertaking | The Chain of Responsibility concept recognises that fatigue may happen because of the actions or inactions of members of the supply chain. These parties include drivers, operators, schedulers, loaders, unloaders, loading managers, prime contractors and consigners including any agents of these parties. Under this concept, parties share responsibility to manage driver fatigue and cooperate and consult with each other to address fatigue risks. Under the Chain of Responsibility parties in the supply chain must take all reasonable steps to check:<br>• the fatigue-management option under which the driver isoperating;<br>• the accreditation details of the operator, if applicable;<br>• that the driver is complying with relevant work, rest andspeed limit requirements; and<br>• that the driver is not impaired, or likely to become impairedby fatigue. |
| Individual Obligations | All workers on-site, including contractors and other on-site service providers, must be involved in implementing the fatigue risk management plan and in making sure it is followed. | Workers (including contractors, apprentices, students, labour hire workers, volunteers) have a duty to ensure fatigue does not create a health and safety risk at work | Workers must take reasonable care for their own health and safety and must not adversely affect the health and safety of other persons | Heavy vehicle drivers have a legal duty to take reasonable care for their safety at work and cooperate with their employers in meeting their obligations |
| Worker Consultation | Consultation must be undertaken as required by legislation | Operators and other PCBUs must consult with workers when developing and implementing strategies to manage fatigue. | A person conducting a business or undertaking must consult, co-operate and coordinate activities with all other persons who have a work health or safety duty in relation to the same matter, so far as is reasonably practicable. | |
| Roles and Responsibilities | The roles and responsibilities of persons within the organisation who will have responsibility for developing and implementing the plan should be identified. | "Roles and responsibilities - fatigue management arrangements should set out the shared responsibilities of the organisation and workers with respect to managing fatigue. Specific fatigue risk management responsibilities should be outlined for managers, supervisors and workers, including contractors." | "A fatigue policy is not mandatory but may be an effective way to communicate the organisation's procedures to workers. Consider including information about:<br>• roles and responsibilities of supervisors and workers" | |
| Resources | Those responsible for the development and implementation of the fatigue risk management plan must ensure that appropriate resources are made available as per their legislative requirements under Queensland legislation. | Operators and other PCBUs responsible for managing fatigue risks must ensure that appropriate resources are made available | "Taking reasonable steps to ensure the business or undertaking has and uses appropriate resources and processes to manage the risks associated with fatigue." | |
| Hazard Identification | Required as part of the four-step risk management process as required under the CMSH regulation | Required as part of the four-step risk management process as required under the WHS (MPS) regulation | Required as part of the four-step risk management process | Required as part of the four-step risk management process |
| Risk Assessment | Required as part of the four-step risk management process as required under the CMSH regulation | Required as part of the four-step risk management process as required under the WHS (MPS) regulation | Required as part of the four-step risk management process | Required as part of the four-step risk management process |
| Risk Control | Required as part of the four-step risk management process as required under the CMSH regulation | Required as part of the four-step risk management process as required under the WHS (MPS) regulation | Required as part of the four-step risk management process | Required as part of the four-step risk management process |
| Hierarchy of Controls | Elimination, Substitution, Isolation, Engineering controls, Administrative controls, PPE | Elimination, Substitution, Isolation, Engineering controls | Elimination, Minimisation<br>The best way to control the health and safety risks arising from fatigue is to eliminate the factors causing fatigue at the source. If elimination is not reasonably practicable, the risks must be minimised. | Elimination, Substitution, Isolation, Engineering controls, Administrative controls, PPE |
| Information, Instruction, Training and Supervision | Required as part of the fatigue risk management plan implementation as required in the CMSH regulation | Information and training - fatigue management arrangements should identify skills and knowledge workers require in meeting their fatigue risk management responsibilities. Supervision - ensure workers and supervisors are competent to identify, report and manage fatigue risks. Fatigue management arrangements should identify skills and training required by workers to carry out their roles and responsibilities under the fatigue management arrangements. | A person conducting business or undertaking must provide, so far as is reasonably practicable, any information, training, instruction or supervision necessary to protect all persons from risk to their health and safety arising from work carried out as part of business or undertaking | Employers and persons conducting a business should provide training and instruction on fatigue for drivers, supervisors, schedulers and any other person whose actions may affect road safety. Specific training requirements are included in the requirements for participation in both the Basic and Advanced Fatigue Management schemes. Employers and persons conducting a business should also provide adequate supervision to ensure that control measures are being used correctly |
| Evaluation of Controls | Required as part of the four-step risk management process as required under the CMSH regulation | Required as part of the four-step risk management process as required under the WHS (MPS) regulation | Required as part of the four-step risk management process | Required as part of the four-step risk management process |

| | Offshore |
|---|---|
| **Fatigue Risk Management Processes** | **NOPSEMA Guidance note** |
| Recognition of Fatigue as a hazard | Fatigue is a hazard that, when not managed effectively, can lead to occupational injury and other adverse health outcomes. |
| Organisational Obligations | The OPGGS Act requires that dutyholders implement and maintain systems of work that are safe and without risk to health. To the extent that fatigue is a hazard with the potential to adversely affect the health or safety of members of the workforce or other persons at or near the facility, dutyholders must take all reasonably practicable steps to ensure that their systems of work appropriately and effectively address the hazard of fatigue. |
| Individual Obligations | |
| Worker Consultation | |
| Fatigue Prevention Barriers | Approproate staffing, rostering, sleep |
| Fatigue Proofing Barriers | Task Scheduling, work environment, behaviour monitoring and response, emergency response and callouts |
| System Monitoring and Improvement | Accident and dangerous occurance investigation, performance indicators |

Appendix B:

# Appendix B – Riskgate Categories – Fatigue

| | |
|---|---|
| **Work scheduling, planning and travel** | Refer to guidance documents |
| | Roster design |
| | Implement fatigue management plan |
| | Work-related travel considerations (daily commute, and commute at start/end of cycle for non-residential workforce) with consideration for local factors (e.g. school bus times) |
| | Additional roster design considerations to manage shift work, particularly night shift |
| | Supervision and interaction during shift |
| | Roster design to consider type of work and adequate rest breaks between consecutive shifts and shift blocks |
| | Specific consideration of fatigue impacts of salaried workers |
| **Work environmental conditions** | Appropriate accommodation for long distance commuting (FIFO, DIDO, etc.) |
| | Appropriate on-site facilities for all workers |
| | Exposure to noise, vibration, thermal extremes - heat, cold, humidity |
| **Mental and physical work demands during shift** | Consider mental and physical task characteristics in design of work |
| **Individual and non-work factors** | Build corporate, workforce, family and community awareness regarding factors that influence individual sleep |
| | Develop, implement and monitor corporate programs that address non-work factors that influence fatigue |
| **Failure to identify fatigue** | Identification of fatigue prior to shift |
| | Role of supervisor |
| | Fail-to-safe design |
| | Manage fatigued individual |
| | Consider using fatigue detection technology |
| | Risk-based task assessment and reassignment where necessary |
| | Performance management |
| | Provision of suitable accommodation pre/post shift |
| | Company provided workforce transportation |
| | Journey management plans |
| | Community awareness programs |

Appendix C:

**42 Safety and health management system for personal fatigue and other physical and psychological impairment, and drugs**

(1) A coal mine's safety and health management system must provide for controlling risks at the mine associated with the following—
(a) personal fatigue;
(b) other physical or psychological impairment;

- Example of other physical or psychological impairment— an impairment caused by stress or illness

(c) the improper use of drugs.

(2) The system must provide for the following about personal fatigue for persons at the mine—
(a) an education program;
(b) an employee assistance program;
(c) the maximum number of hours for a working shift;
(d) the number and length of rest breaks in a shift;
(e) the maximum number of hours to be worked in a week or roster cycle.

(3) The system must provide for protocols for other physical and psychological impairment for persons at the mine.

(4) The system must provide for the following about drug consumption or ingestion for persons at the mine—

(a) an education program;
(b) an employee assistance program;
(c) an obligation of a person to notify the site senior executive for the mine of the person's current use of medication that could impair the person's ability to carry out the person's duties at the mine;
(d) an obligation of the site senior executive to keep a record of a notification given to the site senior executive under paragraph (c);
(e) the following assessments to decide a person's fitness for work—
(i) voluntary self-testing;
(ii) random testing before starting, or during, work;
(iii) testing the person if someone else reasonably suspects the person's ability to carry out the person's duties at the mine is impaired because the person is under the influence of drugs.

(5) The site senior executive must consult with a cross-section of coal mine workers at the mine in developing the fitness provisions.

(6) In developing the fitness provisions, the site senior executive must comply with section 10, other than section 10(1)(a) and (d)(ii)(C), as if a reference in the section to a standard operating procedure were a reference to the fitness provisions.
(a) If the fitness provisions provide for the assessment of coal mine workers for a matter mentioned in subsection (1)(a) or
(b), the site senior executive must establish the criteria for the assessment in agreement with a majority of coal mine workers at the mine.

(7) If the fitness provisions provide for the assessment of coal mine workers for a matter mentioned in subsection (1)(c), the site senior executive must make a reasonable attempt to establish the criteria for the assessment in agreement with a majority of workers at the mine.

(7A) If the majority of workers at the mine disagree with the criteria for the assessment under subsection (7), the criteria for assessment stated in a recognised standard apply until an agreement is reached.

(8) In this section— fitness provisions means the part of the safety and health management system that provides for the things mentioned in subsections (2) to (4).

Appendix D:

Blue - controls placed under two categories

| Riskgate Category | Riskgate Sub-Category | Company 1<br>UG - Coal<br>DIDO - Village<br>Soft | Company 1<br>Hard | Company 2<br>OC - Coal<br>DIDO - Village<br>Soft | Company 2<br>Hard | Company 3<br>OC - Coal<br>DIDO - Village<br>Soft | Company 3<br>Hard |
|---|---|---|---|---|---|---|---|
| Work scheduling, planning and travel | Refer to guidance documents | All rosters reviewed and ranked on the Roster Fatigue Risk Assessment and approved by SSE (inc consideration of risks and controls in QGN16).<br>Coal Mining Safety and Health Act 1999 and Coal Mining Safety and Health Regulation 2017. | | Australian Standard (currently AS/NZS 4308-2008) | | QGN16.<br>The Coal Mining Safety and Health Regulation 2017 | |
| | Roster design | Limitations on maximum shift hours (max hours in 24-hr shift is 18 hrs).<br>Maximum hours of work above 14 hours (inclusive of travel time) requires JSA and SSE approval<br>Limitation on roster design (hours in 28-day cycle not to exceed 224hrs).<br>Limitations on number of 12 hour over time shifts in 28 day period (not to exceed 2).<br>Minimum break limitations (min 10 hours in 24-hr period). | | Limitation on max hours worked (225 hrs on site for 28 day cycle).<br>Limitiation on roster cycle - for a 7/7 and 8/6 roster, a roster cycle is 28 days; or a 5/2 roster, a roster cycle is one week).<br>Limitation on max hours for Mon - Fri day shift office workers (13 hr shift, 65 hrs).<br>Limitations to shift lengths and start times (max hours for all roles and roster types 12.5hrs), and may be on site for up to 13 hours.<br>Limitiations to shift extension (16 hrs).<br>Minimum breaks between shifts 10 hrs.<br>Limitations on shift roster commencement (0500 except with SSE approval).<br>Maximum number of consecutive shifts for CMW s(not more than 9 consecutive shifts of up to 12.5hrs per shift)..<br>Maximum consecutive night shifts (7, SSE approval above that limit)<br>Mimum of 10 hours break between shifts.<br>Additional breaks on nightshift where required.<br>Transitioning from night to day shift and day to night shift limitations (minimum offsite break 24 hours).<br>In-shift break requirements (30 minutes every 5 hrs) and pimarity in crib hut (aircon, seating | | Limitations to shift length - maximum number of hours (12.5 hrs in any 24hr period; 12.5-<14 require supervisor approval; >14 hrs JSA and SSE approval).<br>Limitations to max hours worked per 28 day period (87.5 max per week; 224 max per 28 day period; exceedences of 87.5/wk and 224/28 day require SEE approval)<br>Maximum days shifts for continuous rosters = 10 shifts (for 12hr or greater shifts). (More than 3 days off in a fortnight)<br>Minimum 10hr break between shifts (calculated when swiping on and off at gate)<br>Break after roster equal to roster length for 7 shifts, less than 7 should be 80% (QGN16) - 87.5 maximum hours per week; 125 maximum hours per fortnight; 250 maximum hours per 4 weeks. For worktime beyond these hours, SSE written approval is required.<br>Number of consecutive nightshifts limited to 7 only (QGN16)<br>Break limitations - min number and length in shift (30 mins - 1 break 8-10.5 hr, 2 breaks 10.5-14 hr, min 3 hr between breaks)<br>Where a CMW is contacted (call or text) and it interrupts their sleep, they should consider delaying their start time on site to ensure adequte rest prior to commencement of work.<br>There must be no more than one call out in any 24 hour period. Supervisor approval required prior to | Mandatory swipe on/off site access inc recorded hours. |

| | | | | | | |
|---|---|---|---|---|---|---|
| Implement fatigue management plan | Work outside of the guidelines - approval required from XXXX Manager and SSE, with a JSA.<br>Extended hours greater than 224 hours per 28 day period (requires an approved JSA from XXXX Manager and SSE, and completed XXXX Supervisors Assessment).<br>Critical work roster approval (maximum of 242 hrs per 28 day period) approval required from XXXX Manager and SSE.<br>Maximum hours per shift (14hrs - JSA approved by SSE and completed XXXX; 14-15hrs - JSA approved by SSE, completed XXXX, and must be transported to accomodation; 15-18hrs - tranpsortation to local accomodation).<br>Education in effects of fatigue and contributory factors to fatigue.<br>Auditing process to ensure adequately implemented and complies with regulatory requirements. | | Approval of rosters other than (7/7 D/D, 7/7 D/N, 9/5 Day, 5/2 Day- shift only and 8/6 Dayshift only) are to be approved by the SSE.<br>Shift extensions to 14 hrs - Manager approcal required and RA.<br>Shift extentions to 16 hrs - SSE approval, RA, and additional controls..<br>Limitations on shift roster commencement (0500 except with SSE approval).Limitations on overtime (approval by Manager).<br>Journey Management Plan for all persons (authorised by XXXX Manager / SSE). | | Fatigue Management Plan.<br>Training Needs Analysis determines training requirements regarding fatigue<br>Training and education to CMW's.<br>New rosters - subject to change managment process and approved by SSE.<br>For overtime shifts, approval is required prior to commencing or extending work.<br>Rosters for specialist, non-permanent personnel - RA and SSE authorisation.<br>Review of Journey Management Plan to ensure evidence is correct (changed addresses change commute times).<br>Exceedances to the maximum shift hours are reported to the Supervisor who will manage the risk and record the event in EMS.<br>JMP's are to be completed at the commencement of employment at XXXX Mine and thereafter on an annual basis and when a change in risk level occurs, e.g. change in circumstances, shared driver is on leave, change of origin, change of roster, poor sleep, etc.<br>JMP to be kept on CMW personal file and reviewed if circumstances change in relation to commute requirements | |
| Work-related travel considerations (daily commute, and commute at start/end of cycle for non-residential workforce) with consideration for local factors (e.g. school bus times) | | Transport between the mine and XXXX at the start and finish of rostered work cycles.<br>Transport between the mine and camp accomodation during the rostered work cycle. | Non roster worker (i.e Supervisor) transport to camp requirements - where possible the person is to travel with another person who remains alert for the duration of the journey to and from camp. | Camp accomodation (available for roster workers day prior to their shift, and being available until 10am after their last shift). | | Company transport to/from XXXX at start and end of roster.<br>Company transport to/from camp (unless approved JMP in place).<br>Access to accomodation for CMW's that commute at the beginning and end of rosters. |
| Additional roster design considerations to manage shift work, particularly night shift | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Supervision and interaction during shift | Supervisor monitoring and managing fatigue through observation and undertaking fatigue impairment assessment (XXXX). | | | | Supervisors to conduct safety interactions for tasks identified as a high fatigue risk.<br>Supervisors are required to understake safety interactions with CMW's and consider fatigue as a safety risk.<br>Fatigue observation checklist in Take 5 book. | |
| | Roster design to consider type of work and adequate rest breaks between consecutive shifts and shift blocks | | | | | Supervisor to review if CMW returns without meeting min.(Break limitations - Min break after sequence of night shifts (3-4 $^{3}$2 days break; 5$^{3}$4 days break; 6$^{3}$5 days break; 7$^{3}$7 days break)..)<br>Limitations to consecutive shifts - Dayshift (max 10 consecutive shifts, minimun 3 days off per fortnight).<br>Limitations to consecutive shifts - Nightshift (max 7 consecutive shifts, days off to be equal to roster length).<br>Break limitations - min break btwn shifts (10 hrs offsite; unless emergency or call out)<br>Break limitations - Min break after sequence of night shifts (3-4 $^{3}$2 days break; 5$^{3}$4 days break; 6$^{3}$5 days break; 7$^{3}$7 days break)..<br>Limitations with unplanned work - limits (1 call out in 24 hr period); contols (piror to sleep: shift length $^{3}$16 hours, 10 hr mandatory off); sleep interupted (delay start time; 10 hr mandatory off). | |
| | Specific consideration of fatigue impacts of salaried workers | | | | | | |
| Work environment conditions | Appropriate accommodation for long distance commuting (FIFO, DIDO, etc.) | | Accomodati on for all mine workers during rostered work cycles (availabiel day prior to commencing tour). | | Camp accomodation (available for roster workers day prior to their shift, and being available until 10am after their last shift). | Accomodation village provids gym and healthy food options<br>Self testing alcohol and drug units provided.<br><br>Air conditioned equipment where possible. | Accomodation villages. |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Appropriate on-site facilities for all workers | | Water provided on mine site and at camp accomodation. | | | | | |
| | Exposure to noise, vibration, thermal extremes - heat, cold, humidity | Work in hot and humid environments (XXXX). Working in Heat, Mine and Panel ventilation standards to control work environment temperature). | | | | Consideration of the work environment for dust, noise, hazardous chemicals, vibration or excessive temperatures which have been identified as causing fatigue issues.<br>Protected areas for maintenance where possible.<br>Laser radiation and heat stress controls. | | |
| Mental and physical work demands during shift | Consider mental and physical task characteristics in design of work | Job rotation and rest breaks. | | | | Consideration of task rotation for idenfitied / reported fatigue issues. | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Individual and non-work factors | Build corporate, workforce, family and community awareness regarding factors that influence individual sleep | Individual education / controls: nutrician, exercise, sleep preparation, caffeine, hydration, alcohol and drugs, medication declaration, sleep hygiene, distance travelling). | | Medication declaration form - over the counter medication and prescription medication (must include letter from prescribing doctor). | | Medication declaration from - prescritive and non-prescriptive medications must be reported to supervisor.<br>CMW to present fit for work, monitor alertness levels and obtain adequate sleep.<br>Fitness for work requirements in line with site drug and alcohol plan and physical and psychological plan.<br>Self testing alcohol and drug facilities available.<br>CMWs who have employment in addition to their commitment to XXXX are required to inform their Supervisor to discuss fatigue management. | |
| | Develop, implement and monitor corporate programs that address non-work factors that influence fatigue | | | | | Access to EAP to resolve fatigue related impairment or Supervisor to develop a plan to maintain CMW's fitness for work. | |
| Failure to identify fatigue | Identification of fatigue prior to shift | | | Notify supervisor piror to shift if believe you may be fatigued and/or advise supervisor immediately if experience fatigued. | | Fatigue can be reported by another CMW if a CMW has been identified as suffering the effects of fatigue<br>Fatigue observation checklist in Take 5 book. | |
| | Role of supervisor | Breaches of maximum working hours in a shift to be reported and investigated. | | Notify supervisor piror to shift if believe you may be fatigued and/or advise supervisor immediately if experience fatigued. | | Break limitations - Additional fatigue breaks required - Supervisor to monitor and complete Supervisors Fatigue Checklist.<br>Additional break or task rotation if fatigue issues are reported or identified in consultation with Supervisors.<br>CMW and Supervisor fatigue training | |
| | Fail-to-safe design | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Manage fatigued individual | Hours exceeding 242 per 28 day roster CMW must remain in camp for 12 hours rest unless they live within 50 km (option to arrange transport by fellow worker or family member).<br>Maximum hours per shift (14hrs - JSA approved by SSE and completed XXXX; 14-15hrs - JSA approved by SSE, completed XXXX, and must be transported to accomodation; 15-18hrs - tranpsortation to local accomodation).<br>Incident investigation conducted when person is required to be sent home due to fatigue (inc work and non-work activities). | Fatigue rooms - when workers sent off site due to faituge) | | Camp accomodation (available for roster workers day prior to their shift, and being available until 10am after their last shift).<br>Fatigue rooms upon request through supervisor.<br>Crew bus to and from camp.<br>Crew bus second person in front when 2 or more persons travelling on bus.<br>Engagement of >1 authorised bus driver on each crew. | Management of fatigued CMW's - workers to cease work immediately, supervisor to complete 'Supervisors Fatigue Checklist', and appropriate duties determined (e.g., buddy-up, rest break, transport to camp).<br>Access to EAP to resolve fatigue related impairment or Supervisor to develop a plan to maintain CMW's fitness for work.<br>Individuals encouraged to report fatigue issues to supervisors.<br>Task rotation. | |
| Consider using fatigue detection technology | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Risk-based task assessment and reassignment where necessary | | | | | | |
| Performance management | | | | | If fatigue identified, CMW reports to Supervisor every 2 hours to report on fatigue issues with ongoing Supervisor monitoring during the shift<br>If fatigue identified, CMW can buddy-up with a fellow employee to monitor fatigue<br>If fatigue identified, CMW will be allowed a rest break of sufficient duration and then be reassessed prior to recommencement of tasks<br>If fatigue cannot be controlled, suitable alternate duties will be provided.<br>If, following suitable controls, it is considered the CMW is still fatigued and unable to continue work, arrangements will be made for the CMW to be transported back to camp or local residence<br>CMWs who experience fatigue related impairment at work will be referred to the Employee Assistance Program (EAP).  A Fatigue Management Plan may also be developed in conjunction with the EAP. | |
| Provision of suitable accommodation pre/post shift | | | | | | Fatigue rooms at camp available if CMW cannot commute safely within specified hour limits, including at beginning and end of rosters. |
| Company provided workforce transportation | | | | | | Company transport to/from XXXX at start and end of roster.<br>Company transport to/from camp (unless approved JMP in place). |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Journey management plans | Journey Management Plan for commutes greater than 2 hours. | | Journey Management Plan for all persons (authorised by XXXX Manager / SSE).<br>Journey Management Plan (authorised by XXXX Manager/ SSE) for daily communtes between XXXX.<br>Non roster workers travelling to/from site to find another person to travel with and to manage their own fatigue. | | Journey Management Plan mandatory requirements - travel (2 hrs + at begining / end shift), residence (1hr+ from site), shift lengths (regular 12 hr), and length of wakefulness (may exceed 16 hours while in control of a vehicle).<br>Review of Journey Management Plan to ensure evidence is correct (changed addresses change commute times).<br>CMW to ensure evidence in Journey Management Plan is maintained.<br>CMW to adhere to JMP<br>Where RMI do not provide company transport, a JMP is required for those commuting to/from their home destination to camp<br>Manager approval required to bring personal car to site for those residing at camp | |
| | Community awareness programs | | | | | | |

| Company 4 | | Company 5 | | Company 6 | | Company 7 | |
|---|---|---|---|---|---|---|---|
| OP - Coal<br>DIDO - Village | | Corporate documents | | UG - Coal<br>DIDO? | | UG - Coal<br>DIDO - village | |
| **Soft** | **Hard** | **Soft** | **Hard** | **Soft** | **Hard** | **Soft** | **Hard** |
| The Coal Mining Safety and Health Regulation 2017<br>Department of Natural Resources, Mines and Energy QGN16 Fatigue, Guidance Note for Fatigue Risk Management issued 2013 | | QGN16 Guidance Note for Fatigue Risk Management,<br>Safe Work Australia Fatigue Management<br>OSH Book of Knowledge "Fatigue", 2nd Ed. 2019<br>AS – 4360:2004 Risk Management | | | | All rosters subject to a fatigue risk assessment, comparison against QGN16 and approved by Manager HST and SSE. | |
| Rosters are designed and monitored to minimise impacts on individual's fitness for work.<br>Maximum shift hours for a continuous roster is 12.5 hours (If the shift length is >12.5 hrs. but <14 hrs. Supervisor approval is required; shifts lengths greater than 14 hours a JSA will be required and will require approval by the SSE (or delegate)).<br>A minimum break of 10 hours will occur between shifts.<br>A 30 minute crib break is provided within the first 5 hours from start of shift (workers can self-select breaks around work flow in consultation and with approval from their Supervisor after considering fatigue impacts; The number of crib breaks will be increased to 2 breaks for shifts over 10.5 hours).<br>Maximum number of hours in a permanent roster cycle is 224 in a 4 week period.<br>Unplanned work (overtime, emergencies, break downs call-outs) will be managed by the Supervisor.<br>Short term specialist activities undertaken by non-permanent personnel (e.g. exploration drilling, shut downs etc.) may have different requirements/risks. Rosters for these activities will be developed using the risk | Mandatory swipe on and off at mine site.<br>Gate lockout if break between shifts is less than 10 hours.<br>Site access removed if greater than 224 hours is worked in 28 day period | Maximum hours of work; in a shift, over a 7 day period and roster cycle.<br>Roster design; rotation, consecutive shifts and break between shifts.<br>Provision of adequate rest breaks during shift.<br>Provision of adequate resources and time to complete allocated tasks.<br>Plan to manage any variance to the above (eg: during emergency response or call out work).<br>Management of on-call and emergent work with consideration given to; Minimising impact on sleep opportunity.<br>Management of on-call and emergent work with consideration given to;Provision of additional supports where maximum hours have been exceeded or fatigue has been reported eg; transport home or accommodation arrangements.<br>Site access system to record and monitor accumulative hours across all sites | Onsite login and alcohol testing at commencement of shift | Average week - 60 hours Shift patterns<br>Shifts not planned to start before 5am<br>Maximum number of hours on consecutive night shifts (4 consecutive - $^{3}$10 hours in a shift; 6 consecutive <10 hours in a shift).<br>Minimum break of 24 conseuqtive hours per week.<br>Same shift or forward shift rotation.<br>Set breaks 4 to 5 after commencement of a shift (if>10.5 hrs - 2 breaks, 60 mins total; if > 9 to 10.5 hours - 2 breaks, 45 mins total; and if ≤9 hrs, 1 break, 30 min total).<br>Minimum break between shirts in 10 hours. | | Limitations on maximum shift hours (12.5) and limitiations on number of consequitive shifts (7 day or night shifts)<br>Limitations on roster design (hours in 28-day cylce not to exceed 240hrs)<br>Limitations on shift start times (not between 12 and 5:30am).<br>Rest breaks. | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Resources will be allocated according to risk priority with a view to reduce or eliminate fatigue risk..<br>Employee/contractors who exceed the maximum shift hours are reported to their Supervisor who will manage the risk. | | The Operation is to complete and maintain a documented risk assessment to identify, assess and control the hazards associated with fatigue.<br>Contractor management arrangements to consider: Review and approval of rosters which, as a minimum, meet the requirements of the operations plan for fatigue management.<br>The identification and communication of support services such as; employee assistance programs, early intervention programs, and vaccination programs<br>Identification of training and competency requirements for relevant workers in relation to the management of fatigue and the potential health impacts of fatigue.<br>Changes to organisation, crew or rosters are managed through the change management process, Changes of home or lifestyle routine, Change of role within the company or Change of role outside the company. | | Fatigue Management Work Plan developed and authorised by Department Manager or Site Manager where Fatigue Management Plan not followed. | | All rosters subject to a fatigue risk assessment, comparison against QGN16 and approved by Manager XXXX and SSE.<br>Procedures for Variation to Work Hours and Roster - QGN16 and nominated fatigue assessment tool - sign off by Manger HST and SSE - max shift 16 hours.<br>Fatigue Risk Assessment and WRAC (contractors)<br>Fatigue Management Plan<br>Fatigue Management Work Plans ??<br>Site Induction - fitness for work<br>Comprehensive FFW Training - CMW's and Management.<br>Individual Control: CMW to assess extra shifts. | |
| | Buses are provided for accommodation village/site commuting.<br>Operation personnel residing at the camp are required to use the bus for the full period of each roster including start and finish days.<br>Buses with designated drivers are provided at the start and end of roster to travel to and from XXXX. | Where commute and travel arrangements are identified as having a high potential to induce fatigue consideration should be given to the use of journey plans, inclusive of allocation of bus driving duties. | | | | Take min 4 hr rest at end of last shift prior to driving. | |
| | | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| All Coal Mine Workers (CMW) will be trained in Fatigue Management Programs (FMP) according to the Training Needs Analysis (TNA).<br>Supervisors will manage rest breaks/power naps outside of allocated crib breaks and will investigate the cause of fatigue using XXXX Supervisors Fatigue Checklist.<br>Personal Fatigue Checklists are provided in the TAKE 5 book along with start of shift checks by Supervisors.<br>Specialist training in recognising and managing fatigue issues is provided for Supervisors. | | Identification of training and competency requirements for relevant workers in relation to the management of fatigue and the potential health impacts of fatigue.<br>Assessment of worker tolerance in relation to shift work. | | | | | | |
| | | Contractor management arrangements to consider: Pre-qualification assessment of processes for management of fatigue and fitness for work<br>Contractor management arrangements to consider: Review and approval of rosters which, as a minimum, meet the requirements of the operations plan for fatigue management | | | | | | |
| | | | | | | | | |
| Accommodation will be made available to allow rest periods for persons commuting long distances at the beginning and end of rosters.<br>Provision of gym at the accommodation village.<br>Healthy food options are provided and identified in the mess area at the accommodation village.<br>Accommodation villages provided will be suitable for continuous shift fatigue management. | Well designed and controlled residential camp | Management of on-call and emergent work with consideration given to;Provision of additional supports where maximum hours have been exceeded or fatigue has been reported eg; transport home or accommodation arrangements. | Where accommodation arrangements are provided, controls to minimise sleep disturbance and enhance sleep hygiene;<br>by noise, etc | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | Where accommodation arrangements are provided, controls to minimise sleep disturbance and enhance sleep hygiene…temperature changes and access to appropriate meals and meal times. | | | | Hydration |
| The provision of air conditioned equipment/tinted glass, AM/FM radio, shaded areas for maintenance etc. to provide optimum work environments where possible. | | Where fatigue inducing environmental conditions are identified, consideration is to be given to: Ventilation, Temperature, Lighting levels, Noise and vibration, Ergonomics. | | | Provision of ice machines and drinking water UG. | | Control of work environment hazards - anit-vibration mats, cooling fans, dust extraction. |
| Workload management and self pacing of work. | Job rotation for safety critical tasks and/or monotonous work and/or heat and other environmental conditions.<br>Monitoring and rescheduling mentally demanding work | Task rotation (e.g. for monotonous tasks)<br>Communication and other stimulus during shift<br>Mechanical aids (e.g. for physically demanding task). | Fixed / mobile plant induces or catalyses - Vibration matting to reduce vibration, Seat suspicion in heavy vehicles (surface operations only), Equipment seals, Temperature controls in mobile plant and buildings (where practical), and Acoustic control and noise attenuation. | | Job rotation - to reduce effects of heat and humidity (rotating manual task and areas of higher effective temperatures). | | Task rotation - limiting duration of monotonous, or physically/ psysiologically demanding work. |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| All Coal Mine Workers (CMW) will be trained in Fatigue Management Programs (FMP) according to the Training Needs Analysis (TNA).<br>All medications (prescriptive and non-prescriptive) taken, that have the potential to effect fitness for work, must be reported to your Supervisor.<br>All coal mine workers have a responsibility to present fit for work, monitor levels of alertness and obtain adequate sleep so as to not create an unacceptable risk.<br>Employees who have employment in addition to their commitment to are required to inform their Line Manager to discuss fatigue management.<br>Screening for sleep disorders and other medical conditions affecting sleep in high risk populations.<br>'No blame' culture that supports early intervention for legitimate health issues and alternate duties | | Individuals must ensure that they obtain adequate quality sleep to prevent fatigue.<br>Home arrangements promote adequate sleep (eg black out curtains, aircon, earplugs, family arrangements). This is especially important for shift workers who should actively plan to obtain adequate quality sleep.<br>Individuals must exercise particular care to prevent fatigue at critical times such as a change in roster, first night shift or when returning from a period of leave.<br>Systems that encourage the self-reporting and peer-reporting of fatigue.<br>Systems to detect and identify fitness for work issues such as; medicals, drug and alcohol screening, declaration process for medications and medical conditions.<br>Self / family recognition and intervention. | | Access to confidential councelling service through EAP (drug and alcohol).<br>Access to addicition programs. | Drug and alcohol testing - pre-employement, random, challenge, post-incident and voluntary. | Individual control - Personal Fatigue Management Plan.<br>Sufficient rest before presenting for first shift. | |
| An Employee Assistance Program (EAP), along with employer support, will be provided for individuals having difficulty managing fatigue.<br>EAP is available to help individuals manage personal issues that may be causing or could cause fatigue issues such as sleep disorders, financial concerns, personal issues etc. | | The identification and communication of support services such as; employee assistance programs, early intervention programs, and vaccination programs.<br>Workers seek support through internal or external services (supervisor, EAP, mates in mining). | | | | | |
| Personal Fatigue Checklists are provided in the TAKE 5 book along with start of shift checks by Supervisors.<br>Coal Mine Workers are encouraged to readily and effectively report fatigue issues to their Supervisors.<br>CMWs to report fatigue issues with tasks to their Supervisors. | | Individuals who feel fatigued when presenting for work, or while on shift must inform their supervisor if they consider there is a possibility that they may present a safety risk.<br>Systems that encourage the self-reporting and peer-reporting of fatigue. | | | | Individual control - reporting fatigue issues that impact their performance. | |
| Field leadership to be carried out by Supervisors for tasks identified as a high fatigue risk. | | Where work tasks are identified as having a high potential to induce fatigue, consideration is to be given to: Supervison arrangements.<br>Additional sleep opportunity provided when on-call arrangements have been enacted.<br>Supervisor observes fatigued worker and intervenes | | | | Individual control - reporting tasks with the potential for fatigue | |
| | | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Option of task rotation is to be considered if fatigue issues are reported or identified in consultation with Supervisors.<br>EAP is available to help individuals manage personal issues that may be causing or could cause fatigue issues such as sleep disorders, financial concerns, personal issues etc. | | Processes for management of workers identified as fatigued.<br>Workers declare potential physical or psychological impairment (inc medications) | | | | | Transportation of CMW to and from camp - bus - mandatory for all working 12 hr shifts. |
| | | | In-vehicle operator awareness monitoring system for high utilization (night shift) haul trucks - Guardvant.<br>Operations are to consider...Proximity detection systems to alert and alarm impending vehicle interactions<br>Operations are to consider...Collision avoidance systems to minimise<br>risk of vehicular collision.<br>Operations are to | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Specialist training in recognising and managing fatigue issues is provided for Supervisors. | | Identification of safety critical tasks with consideration given to: TARPS to assist with decision making, and Requirement for verification of decisions.<br>TARPS for Principle Hazards to assist with decision making | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| A Journey Management Plan (JMP) is to be developed and signed by the Department Manager for individuals who live in their own dwelling more than 50km from site and who commute to and from site every roster day.<br>A JMP is to be developed for individuals travelling 200km or more to work at the beginning and end of shift.<br>Share/Car-pooling for personnel travelling from local townships.<br>Department Manager or delegate permission is required to bring personal car to site.<br>Fatigue room at each end of roster if required by JMP | | Where commute and travel arrangements are identified as having a high potential to induce fatigue consideration should be given to the use of journey plans, inclusive of allocation of bus driving duties.<br>Workers who self FIFO / DIDO must ensure they fit for work post travel as per Fatigue Management Procedure and are responsible for their journey management | | | | Commute Management Plans ??<br>Take min 4 hr rest at end of last shift prior to driving. | |
| | | | | | | | |