Safety in Mines Research Advisory Committee

Final Report

Factors affecting driver alertness during the operation of haul trucks in the South African mining industry

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Executive Summary

Alertness during extended or undemanding tasks is essential for safety and productivity. Over the past decade attention has been increasingly focused on sleep and problems related to sleeplessness. It is now recognised that sleepiness and fatigue are becoming endemic to the populations of industrialised societies: sleepiness and fatigue contribute to human error and consequently to many (sometimes catastrophic) accidents. Long hours of undemanding and monotonous driving, such as during certain mining operations, facilitate the onset of sleepiness as does any other tedious task. A number of accidents, which may be attributed to loss of control due to sleepiness of drivers, have been reported at mines where haul trucks are used.

In view of the seriousness of such accidents, SIMRAC initiated research to identify factors affecting haul truck driver alertness during mining operations. The information obtained during the risk analysis was used to identify possible countermeasures and detection devices to reduce the identified risks.

Risk analyses of the tasks of haul truck drivers were carried out at four mines, with the focus on factors that influence operator-equipment interface, physical stressors, work organisational factors, and a number of life-style issues that could influence sleep susceptibility. Subjects were also required to rate their subjective sleepiness at work at different times during the shift by means of the Wits SleepWake Scale.

From the literature and observations made during the field assessments, the thirteen factors listed below may compromise the alertness of the drivers of haul trucks during mining operations.

? Disruptions in circadian rhythms associated with phase shifting in sleep/wakefulness cycles

? Inadequate (shortened) sleep

? Poor quality of sleep between shifts

? Fatigue

? Daytime sleepiness

- ? Sub-optimally designed shift schedules (unusual work schedules)
- ? Time of day
- ? Night shift driving (greater tendency towards drowsiness)
- ? Extended driving times
- ? Monotonous nature of tasks
- ? Certain medical conditions (e.g. obstructive sleep-apnoea syndrome) and medications
- ? Poor awareness of the causes and consequences of fatigue, and the importance of sufficient sleep and ways to achieve it
- ? Lifestyles.

Countermeasures that could alleviate sleepiness and enhance alertness in haul truck drivers would be well-designed shift work schedules, sufficient rest days in the work schedule and structured breaks during the shift, proper sleep management, professional health screening and counselling, educational programmes, appropriate food and fluid intake, and devices to measure driver wakefulness during driving.

On the basis of the findings of the study, it is concluded that irregular work schedules disrupt the normal circadian rhythm. This disruption causes sleepiness when wakefulness is required and insomnia during the main sleep episode. The disruption of the normal circadian rhythm and its associated effects also applies to haul truck operators in the South African mining industry, as driver sleepiness is a reality and a safety risk. Poor quality and quantity of sleep have been identified as major risk factors in the reduced alertness of haul truck drivers during mining operations. It is therefore recommended that interventions and countermeasures should be implemented to address these problems as a matter of priority. Managing sleep and designing work schedules are of critical importance and require participatory planning and implementation. The countermeasures outlined in this report could form the basis of a strategy to reduce driver sleepiness.

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1 Introduction

Drowsy driving is a key factor in many motor vehicle accidents as it makes drivers less attentive, slows their reactions and impairs their judgement. Driving is a type of task known to be fatiguing: it is monotonous and repetitive but at the same time requires sustained attention. A 'drowsy driver' is in a state of drowsiness, i.e., the intermediate stage between wakefulness and sleep that can be measured electro-physiologically by the pattern of brain waves (electroencephalogram or EEG), and by measuring eye movements and muscle activity. Drowsiness is accompanied by many psycho-physiological changes that are anathema to safe driving, such as the impairment of visual perception, the inability to maintain visually focused attention, and the impairment of higher cognitive functions (Johns, 2000).

Over the past decade, increasing attention has been paid to sleepiness and sleep-related problems, mainly due to the recognition that sleepiness and fatigue are becoming endemic to the population, contributing to human error and, consequently, to many (sometimes catastrophic) accidents in industrialised societies. Although recent estimates of the percentage of injuries and fatalities caused primarily by sleepiness or fatigue diverge considerably, varying from 2% to 41% (Ferrara and De Gennaro, 2001), these accidents involve enormous costs in terms of lives and money.

Despite the renewed interest in sleep-related problems, there is no complete agreement on a definition of fatigue. Earlier researchers distinguished between the physiological consequences of prolonged activity, which they termed 'impairment', and the psychological consequences, including poor performance and negative feelings, which they termed 'fatigue'. More recently, it has become clear that poor performance reflects the impact of fatigue on the effectiveness of task performance and does not reflect a decline in the efficiency of performance (Hartley, 2001). Fatigue is also defined as "a state of declining alertness which eventually ends in sleep". Such a definition has merit in drawing attention to the key deficits that occur, such as the decrease in the speed with which decisions are made, including the ability to make controlled manoeuvres in a vehicle.

Long, undemanding and monotonous driving, such as experienced during certain mining operations, facilitates sleepiness as does any other tedious task. A number of accidents, which could be attributed to the loss of control due to the sleepiness of drivers, have been reported at mines where haul trucks are used. In view of the seriousness of these accidents, SIMRAC was approached to initiate research into identifying the factors that affect driver alertness during transport operations. It became evident that a study was required to assess whether or not significant risk exists, and whether it is necessary for preventive measures to be put in place.

Local and international safety statistics indicate that ergonomic factors underlie many of the accidents mentioned. Broadly speaking, there are three factors that may contribute to an accident: management systems (methods and procedures), conditions (facilities and equipment) and the critical things that people do. These three factors form the working interface and ergonomic interventions can be used to improve the working interface with the direct benefits in the form of improved safety performance.

2 Objective of the Study

The objective of the study was to identify factors that could potentially affect driver alertness during the operation of haul trucks in the course of mining operations. The information obtained during the risk analysis would then be used to identify potential countermeasures and equipment to reduce the recognised risks.

3 Methods

Data collection to identify the causal factors of sleepiness in the project consisted of three phases. The first phase was a review of studies published in the scientific literature dealing with the role of driver/operator sleepiness in worker fatigue and accidents. Data on transport accidents involving haul trucks were obtained from the South African Mines Reportable Accidents Statistical System (SAMRASS) and were analysed to identify probable causal factors. Similar statistics obtained from two of the project mines were also analysed.

The second phase of the project was field evaluation and analysis of the tasks of haul truck drivers at four mines. One mine was re-evaluated after change to the shift system was implemented. In this phase, the focus was placed on the 'ergo system' in order to identify the factors influencing the operator-equipment interface. Physical stressors in the driver's cabin, such as heat exposure (using Hiker temperature monitors) and noise levels (using B&K noise-level meters) were determined. In addition, work organisational factors (shift systems, day-to-day operation schedules) and the ergonomics design (workstation layout) were also evaluated.

The third phase was aimed at obtaining information on social and lifestyle habits that could contribute to sleepiness. For this purpose, subjects were asked to complete a questionnaire (see Appendix A). They were also required to rate their level of perceived sleepiness at work at different times of a shift schedule by means of the Wits SleepWake Scale (Maldonado, *et al.*, 2003). Seventy operators at the four mines agreed to participate in this phase of the study.

The Wits SleepWake Scale is a pictorial scale of five cartoon faces depicting degrees of sleepiness (Figure 1) and, every hour for the duration of a shift, operators marked the face that best described how sleepy or alert they felt at that time. Thurstone's scaling procedure was used to transform the individual scores to a consolidated interval scale.

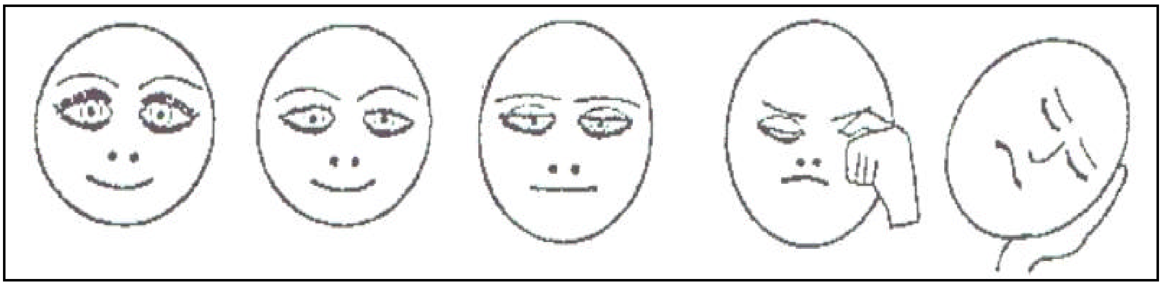

Figure 1: Pictorial scale of the Wits SleepWake Scale

Sixty-six male operators of haul trucks from four mines (two opencast collieries, one opencast iron ore mine and one opencast manganese mine) participated in the study on the basis of informed consent. One of the coal mines was surveyed on two occasions, following a substantial change in its shift schedule. The methods used were approved by the Committee for Research on Human Subjects of the University of the Witwatersrand (Clearance Certificate Protocol Number M02-07-32).

4 Results and Discussion

4.1 Literature Review

From the literature, it is evident that sleepiness and reduced vigilance are important risk factors for accident proneness at work (Åkerstedt, 1994). Leger (1995) calculated that as many as 53% of all work-related accidents in 1988 in the USA were potentially related to sleepiness. Sleepiness and sleep disturbances have been shown to increase the frequency of occupational accidents (Lindberg *et al.*, 2001).

The two most frequently recognised factors related to automobile accidents are speeding and alcohol, but inattentiveness, fatigue and sleepiness are primary or contributing factors (Stradling, 1989). Driver alertness has a great impact on safety. Drowsiness and sleeping at the wheel have been identified as the major reasons behind fatal crashes and freeway accidents caused by car and/or truck drivers (National Transportation Safety Board [NTSB], 1990). Connor *et al.* (2001) have shown that there is an odds ratio of 2.7 between sleeping less than 5 hours (5 h) in the last 24 hours (24 h) compared to more than 5 hours sleep and being implicated in a sleep-related accident. Driving between the hours of 02h00 and 05h00 was associated with accidents with an odds ratio of 5.6 compared to driving at any other time of the day.

Populations that have been shown to be at a higher risk of involvement in sleep-related vehicle accidents include young people, people with undiagnosed or untreated sleep disorders (Aldrich, 1989), drivers who have taken soporific medication such as benzodiazepine anxiolytics or sedating antihistamines (Ray *et al.*, 1992; Ceutel, 1995), and night or rotating shift workers (Dalziel and Job, 1997; Marcus and Loughlin, 1996). Commercial vehicle operators are also at increased risk of drowsy driving and sleep-related accidents due to factors such as extended driving times, irregular work and sleep schedules, higher frequency of night-time driving and inadequate sleep (Bass *et al.*, 2000; McCartt *et al.*, 2000), and disturbed or poor-quality sleep (Maldonado *et al.*, 2002).

For anyone who is already drowsy, the consumption of alcohol can pose a special risk. Research has shown that alcohol and sleep loss interact additively to increase levels of sleepiness (Zwyghuizen-Doorenbosh *et al.*, 1988; Lumley *et al.*, 1987), often with fatal consequences.

Fatigue is a dimension ranging from declining performance on vigilance tasks (inattention), through to outright falling asleep. Numerous factors contribute to fatigue and sleepiness but knowledge about the relationships between these factors and accidents remains limited. Connor and co-workers (2001) concluded that the direct epidemiological evidence for a causal role of fatigue in car accidents is weak, but is suggestive of an effect. Since accidents are commonly multifactorial, estimating the independent effect of fatigue will depend on the simultaneous measurement of other potential contributing causes, as well as on confounders of the relationship, and on considering the interactions between fatigue and other factors, such as alcohol.

Although sleep may be the endpoint of fatigue, human performance often deteriorates to unsafe levels long before sleep (Mackie & Miller, 1978). Hartley and Mabbott (1998) have listed the following as problems for heavy vehicle operators long before sleep onset:

? slow reaction and decisions,

? slow control movements,

? decreased tolerance for other road users,

? poorer judgement when overtaking,

? poor lane tracking and maintenance of headway speed, and

? loss of situational awareness.

Most of the studies in the literature dealing with falling asleep at the wheel involved long-distance truck drivers. Comparing the results of these studies is difficult, given the variety of experimental designs, differing outcome and predictor measures, differing sampling frames and methods, and sometimes inconsistent findings. Generally, however, these studies suggest that sleepiness-related driving among long-distance truck drivers is associated with variables that are related to drivers' schedules, particularly their patterns of working and resting, and their individual sleep needs and patterns.

There are clearly defined similarities and differences between operators of long distance transport haulage and operators of machinery in mining operations. Similarities include:

? long duration of monotonous scenery,

? a mainly sedentary occupation; and

? working through periods of time when circadian rhythms naturally encourage sleep.

Basic differences would include the operator of coal mining machinery having interruptions in the driving task by having to stop and reverse the vehicle often (Haulpak operators especially), while truck drivers drive long distances in one direction. Another difference is the interaction of coal mining machinery operators. These operators must constantly monitor the position of their workmates for both safety and performance reasons. Truck drivers often travel kilometres of isolated road before encountering another road user. Regardless of similarities and differences, a lapse in vigilance or a reduction in performance by either operator may lead to an incident or accident.

In a study conducted in Australia, the Axtat incident database of the Australian Department of Minerals and Energy was analysed to determine the occurrence of accidents for operators of heavy machinery in open-cut coalmines (Mabbott et al., 1999). Five years of data (01/07/93 – 30/06/98) were analysed to extract information relevant to driving occupations, mobile plant, and excavation operations specifically. 93% of the incidents in the driving occupations were possibly fatigue related. The most common injury of possible fatigue-related incidents was ascribed to equipment jolting and jarring, mainly as a result of the fact that the tired operators handled equipment in a different way than they would if they were vigilant. The total cost to the Australian coal mining industry for injuries and lost time due to possible fatigue-related accidents for the period in question was $ 3 345 000. In view of the limited information relating to the timing of fatigue-related accidents, Mabbott and his co-workers suggested the Axtat database be upgraded to include the time when the accident occurred, the number of hours worked up to the time of the accident, and the cost of damage to machinery.

4.1.1 Number and pattern of hours worked

The first of seven major variables linked with sleepiness-related driving is the number and pattern of hours worked. Mackie and Miller (1978) conducted an experiment from which they found that driving performance among truck drivers declined after more than 8 hours of driving for regular schedules, and after more than 5 hours of driving for irregular schedules. In another experimental study, Harris (1972) found that driving performance, as measured by the number of crashes, declined after 4 hours of driving. The relative risk of an accident for drivers who did more than 8 hours of driving was found to be twice that of drivers who drove fewer hours (Hartley, 2001). Williamson *et al.* (1996) found that fatigue increased over the duration of trips, regardless of the driving regime, although the pre-trip level of fatigue was a primary factor in fatigue experienced while on the road.

4.1.2 Time of the day

A second variable, the time of day, has also been identified as predictive of sleepiness-related driving among truck drivers and light motor vehicle drivers (Horne and Reyner, 1995). On the basis of physiological and performance data, a US/Canadian Driver Fatigue and Alertness Study found that the strongest and most consistent factor influencing driver fatigue and alertness was time of day, rather than time on the task or number of trips (Wylie *et al.*, 1996).

Truck crashes in which drivers were dozing were seven times more frequent between midnight and 08h00 than at other times of the day, and the highest risk was between 04h00 and 06h00 (Hartley, 2001). A Swedish study found that the single-truck crash risk increased by a factor of 4 between 03h00 and 05h00, while the physiological records of drivers' brain waves showed greater sleepiness when they were working at night, especially after midnight (Hartley, 2001). Horne (1992) found that individuals driving between 04h00 and 06h00 were 13 times more likely to have a sleep-related accident than someone driving during any other two-hour period. In addition, Maycock (1995) found that tiredness-related accident involvements, as a proportion of all involvements, are greatest in the early hours of the morning (27% between midnight and 04h00; corresponding to 36% of accidents), falling to a minimum of 3% (4% of accidents) in the morning hours (08h00 to midday), and rising thereafter through the afternoon and evening periods.

4.1.3 Quantity and quality of sleep

Substantial research has also demonstrated the link between sleepiness-related driving and a third variable, namely the quantity and quality of sleep. The 1995 National Transportation Safety Board (NTSB) study found that predictors of sleepiness-related accidents were the duration of the driver's last sleep period, the total sleep obtained during the 24 h preceding the crash, and fragmented sleep patterns. Arnold *et al.* (1997) reported on significant sleep deprivation among professional drivers in an Australian state, and recently it was found that self-reported short sleep (brief naps that lasts for around 4 to 4 seconds) was predictive of falling asleep at the wheel (McCartt *et al.*, 2000). Tempas and Mahan (1989) stated that many fairly common work schedules interact antagonistically with sleep, particularly those shifts that include some degree of night-time work.

Earlier research and theory of the 1960s on the effects of attempting to sleep during other than habitual sleeping times suggests that night-shift workers have a tendency to suffer from an insomnia-like sleep disorder and consequently, these individuals have difficulty falling and staying asleep. However, later research of the 1980s on experienced night-shift workers has provided a different view of the sleep-work relationship. Ordinarily, individuals make a choice as to what time they will sleep. Most individuals who work through daylight hours elect to take their main sleep period just before going to work. On the other hand, most night-shift workers elect to take their main sleep period just after finishing work. Thus, there is not only a variation in the order in which different shift workers sleep but also in the time of the day at which they sleep. Night-time workers have a reduction in total sleep time and are susceptible to suffering from chronic sleep debt.

4.1.4 Obstructive sleep apnoea

A fourth variable linked to sleepiness-related driving is obstructive sleep apnoea, characterised by severely disturbed breathing during sleep. Factors affecting this disorder include obesity, snoring, sleep interrupted by intermittent gasping for breath, and excessive daytime sleepiness (Lloberes *et al.*, 2000). Several studies (George *et al.*, 1987; Haraldsson *et al.*, 1990) have shown a 2- to 12-fold greater rate of driving accidents in patients with snoring and obstructive sleep-apnoea syndrome (OSAS) than in subjects without sleep apnoea. The extent of daytime sleepiness, which is related to sleep apnoea, has also been related to sleepiness-related driving. On the basis of drivers' self-reports, McCartt *et al.* (1996) found that the frequency of drowsy driving was related to the frequency of trouble in staying awake during the day and the number of hours that could be driven before the onset of drowsiness.

4.1.5 Shift work

A fifth variable is shift work, which is increasing in modern society as an important tool for flexibility of work organisation. Shift-work schedules can be organised in a large variety of ways and may include day work plus one or more shifts worked outside of these normal day-work hours. On shift work, and particularly on night work, workers are compelled to alter their normal sleep-wake cycle according to the changed activity and rest periods. This interferes with the regular cycles of bodily functions (circadian rhythms). This rhythmicity is controlled by a 'body clock', located in the suprachiasmatic nuclei, and is influenced by environmental 'synchronisers', in particular, activity, sleep and light exposure.

Shift workers have to change their sleeping times and strategies according to their duty periods. Consequently, both the length and quality of sleep can be considerably affected according to the erratic retiring and rising times on the different shifts. On night shift in particular, the subsequent length and quality of diurnal sleep is affected for physiological reasons: it is difficult to fall asleep and stay asleep for a long period if sleep has started during the rising phase of the body temperature cycle (usually between 06h00 and 10h00). Attempting to sleep in unfavourable environmental conditions (light and noise in particular) also tends to result in sleep that is shorter, frequently interrupted and altered in its stage sequencing. As the circadian rhythms of most night workers do not shift phases, the workers are in a constant state of circadian misalignment, and are forced to work during the 'wrong' circadian phase (when their bodies are ready to sleep) and they then try to sleep during the 'wrong' circadian phase (when their physiology is primed for alertness) (Burgess *et al.*, 2002). In the long run, sleep perturbations and deprivations, besides having an influence on the desynchronisation of circadian rhythms and causing 'shift-lag' syndrome, can yield persistent and severe disturbances of sleep itself, chronic fatigue and psychoneurotic syndromes (such as chronic anxiety or depression), which often require treatment (Costa, 2001).

4.1.6 Night work

The sixth major variable is that night work is associated with increased subjective and objective sleepiness. For instance, changes in the electroencephalogram (EEG) indicating drowsiness or light sleep have been observed in train drivers (Torsvall and Åkerstedt, 1987), truck drivers (Kecklund and Åkerstedt, 1993) and control room operators (Gillberg *et al.*, 2003). In these studies the subjects clearly felt sleepier during the night shift and the electro-physiologically estimated sleepiness, although low, was significantly higher at the end of the night shift compared with the end of the day shift.

A recent case-control study (Stutts *et al.*, 2003) has identified a number of factors, also implicated in other studies, which appear to increase a driver's risk of involvement in a sleep-related motor vehicle accident. These include holding multiple jobs, working a night shift, averaging less than 6 h of sleep per night, poor overall quality of sleep, excessive daytime sleepiness, frequent night-time driving (especially between midnight and 06h00), using soporific medications, driving after being awake for more than 15 h, and driving after sleeping less than 5 h the night before. Interestingly, one of the strongest risk factors identified in this study was a history of driving while drowsy. The results demonstrated a strong dose-response relationship and suggest that, like drinking drivers, drowsy drivers may accumulate considerable experience of driving while their skills are impaired, prior to crashing.

4.1.7 Work-related fatigue

Irregular work and sleep patterns are associated with increased work-related fatigue, decreased alertness and increased accident risk. In a study conducted in the Australian mining industry (Maher, 2001), the following accounts of fatigue-related incidents typifying chronic sleep deprivation, overwork, poorly designed roster systems, and inadequate training on managing shiftwork were identified:

- ? operators falling asleep whilst driving vehicles and crashing the vehicle,
- ? delirium and loss of situational awareness (drivers not aware of where they are or job they have just completed),
- ? equipment damage through lapses in concentration and decreased accuracy,
- ? high levels of absenteeism due to extended hours, and
- ? evidence of employees with sleep problems.

Studies of fatigue 'intoxication' were recently conducted by Dawson and Reid at the University of South Australia. The test results confirmed that tired people perform about as well as those who are legally drunk. In each case, the subjects were kept awake for up to 27 hours and performed simple tasks every hour: matching up colours and letters on a computer screen and tapping the keyboard in response to numbers flashing on the screen. Putting these subjects behind the wheel of a driving simulator after the 27-hour awake period provided additional information on the level of their performance. On another day, without sleep deprivation of any kind, the subjects were given shots of vodka and orange juice to build up their blood alcohol levels and the subjects then performed the same battery of simple tests. The results showed that after being awake for 17-18 hours, human performance is impaired to the same level as that of a blood alcohol content of 0.05%. After 21–22 hours of being awake (typical for night-shift workers), the ability to perform simple tasks is impaired to the same level as that of a blood alcohol content of 0.08% and, after 23,5 hours, 0.10% – legally drunk anywhere in North America (Sirois, 2003).

The results of a study by Horne and his co-workers (2003) showed that modest and apparently 'safe' levels of alcohol intake exacerbate driving impairment due to sleepiness. The sleepy drivers in their study seemed not to have realised that alcohol had increased their sleepiness to an extent that was clearly reflected by a greater driving impairment and changes in the EEG pattern.

From the literature on the effect of shift work in female workers, it is evident that shift work may have adverse effects on women's health (Costa, 1996). It has been documented that married female night workers with children have shorter and more frequently interrupted sleep than their day-time counterparts (Dekker and Tepas, 1990). Women involved in shift and night work had high frequencies of disturbance of their menstrual cycles and experienced menstrual pains (Uehata and Sasakawa, 1982). Shift work has also been identified as a factor in the preterm delivery of babies and/or low birthweight (McDonald et al., 1988; Nurminen, 1989).

4.2 Accident Statistics

4.2.1 SAMRASS

A total of 104 accidents involving haul trucks resulting in 40 fatalities and 70 injuries were reported over the period 1995 to 2002 to SAMRASS. Of these, 23% of the accidents involved haul trucks in the 10-19 ton category, 57% involved haul trucks in the 20-99 ton category, 18% involved haul trucks in the 100-199 ton category, and 2% involved haul trucks in the 200-299 ton category.

A breakdown of accidents per commodity is given in Table 1. Most of the accidents (31%) occurred on coal mines, 12% at iron-ore mines and 10% at gold mines.

Table 1: Accidents involving haul trucks per commodity

Commodity	Fatality	Injured	Disabled	Accidents
Clay		1		1
Chrome	1	2		3
Coal	14	18		32
Copper	5	1		5
Diamonds	2	3		5
Dolerite	1	1		2
Dwyka		1		1
Fluorspar		1		1
Gold	4	7		10
Granite	1	4		3
Gravel	1			1
Iron-ore	2	10		12
Kaolin		1		1
Limestone		4		4
Malmesbury Hornfels	1	1		2
Manganese	3	1		3
Phosphates	2			2
Platinum Group Metals	2	5		7
Quartzite Dimension Stone		3		2
Sand		3		3
Silica	1	1		2
Titanium		1		1
Zinc		1		1
TOTAL	**40**	**70**	**0**	**104**

Table 2: Probable causes of accidents involving haul trucks

Cause of accident	Code	Accidents	Fatality	Injured
Pre-placement medical not done	01A01	1		1
Physical shortcomings	01A04	1		1
Poor judgement	01B07	9	3	6
Workplace not modified to accommodate personal shortcomings	01C01	1	1	
Lack of knowledge regarding safety aspects of job	02A04	17	6	11
Lack of practice under supervision	02B05	1	1	
Hazardous nature of job causes stress	04C06	1	1	
Routine/monotonous work	04C10	1		1
Habit/personal preference	06A03	3	2	3
Other	06A05	1		1
Inadequate policy/guideline/procedure	07B08	1		1
All risks not assessed in conceptual stage	08A01	3		3
Factors that lead to incident not identified in design stage	08A02	1	1	
Risk of interfacing operations not assessed	08A03	1	1	
Safety specifications not researched for design	08B01	1		1
Standards and procedures/Codes of Practice not researched for design	08B03	1		2
Wrong tools supplied	11A01	1		1
Wrong/substandard equipment	11B01	3	1	2
No/inadequate system to prevent use of unsafe equipment	11B02	1		1
Equipment defects not reported	11B03	1		1
Not registered for planned maintenance	11B05	3	1	2
Equipment available but not used	11B06	1	1	
Damaged or unsafe material used	11C03	2		2
Abnormal use/overloading/excessive speed	11E04	1	2	
Inadequate maintenance of standards	12A03	40	18	22
No/inadequate task analysis	12B01	1		1
Procedure not used for training purposes	12B02	1		1
No specific rule to control actions that led to incident	12B03	1	1	
Procedures inadequate	12C02	2		2
Training programme inadequate	12C08	2		3
Miscellaneous	13A01	1		1
Total		**104**	**40**	**70**

In 38% of the accidents reviewed in Table 2, 'inadequate maintenance of standards' was given as the cause and in 16% of the accidents, 'lack of knowledge regarding safety aspects of the job'. 'Poor judgement' was identified as a causal factor in 9% of the accidents. Not a single accident has been ascribed to "fatigue due to lack of rest" (SAMRASS code 04B06).

Although SAMRASS is an excellent system for providing statistics, it cannot really be used for more detailed analysis of the probable causes of and circumstances surrounding accidents, such as environmental and other mining-related factors surrounding accidents. Addressing this shortcoming would increase the potential for using SAMRASS as an important tool in devising accident-prevention strategies.

4.2.2 Mine A

Statistics dealing specifically with haul trucks were only available at two of the mines used in the study.

At Mine A accident statistics for one calendar year included 35 accidents involving haul trucks. In only four (11%) of these accidents were 'sleepiness' and/or 'falling asleep' given as the probable cause of the accident. The times at which these accidents occurred were 11h30, 02h15, 06h15, and 06h57 respectively.

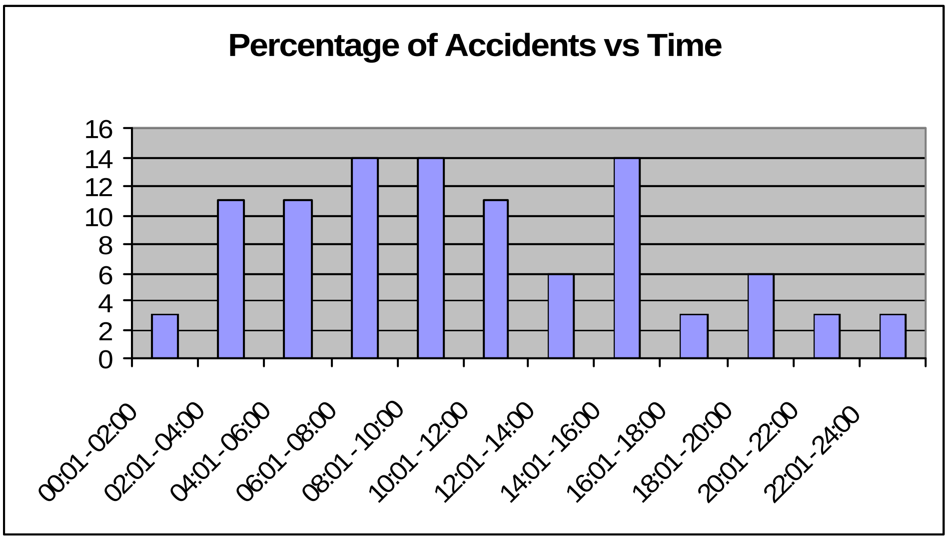

Figure 2: Time distribution of accidents involving haul trucks at Mine A

Figure 2 depicts the time distribution of the total number of haul-truck accidents: 46% of the accidents occurred during the morning shift (08h00 – 16h00), 14% during the afternoon shift (16h00 – 24h00), and 40% during the night shift (00h00 – 08h00). All shifts had the same number of haul trucks. Most of the accidents occurred at the beginnings and endings of the shifts: 14% respectively at the beginning of the morning shift (08h01 - 10h00), the end of the morning shift (14h01 - 16h00), and at the end of the night shift (06h01 - 08h00).

4.2.3 Mine B

A total of 27 damage-related accidents involving haul trucks were reviewed (Figure 3): 48% of the accidents occurred during the morning shift (08h00 – 16h00), 4% during the afternoon shift (16h00 – 24h00), and 48% during the night shift (00h00 – 08h00). Most of the accidents (24%) occurred between 04h01 and 06h00 and between 10h01 and 12h00.

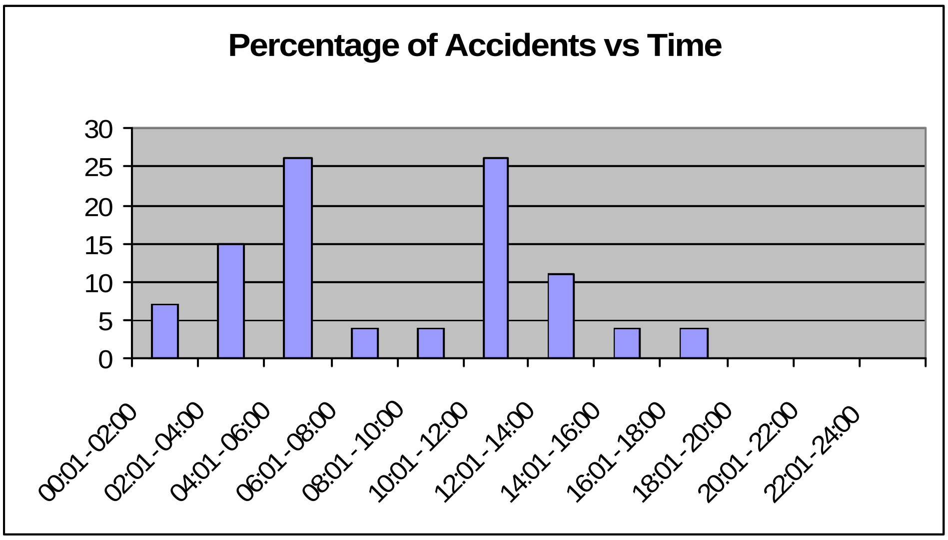

Figure 3: Time distribution of 'damage-related' accidents involving haul trucks at Mine B

Another 31 haul-truck accidents which resulted in injury were analysed (Figure 4). These accidents occurred over the period 1997 to 2002. It was found that 48% of the accidents occurred during the morning shift (08h00 – 16h00), 26% during the afternoon shift (16h00 – 24h00) and 26% during the night shift (00h00 – 08h00). Most of the accidents (26%) occurred between 10h01 and 12h00 and 23% at the beginning of the afternoon shift (16h01-18h00).

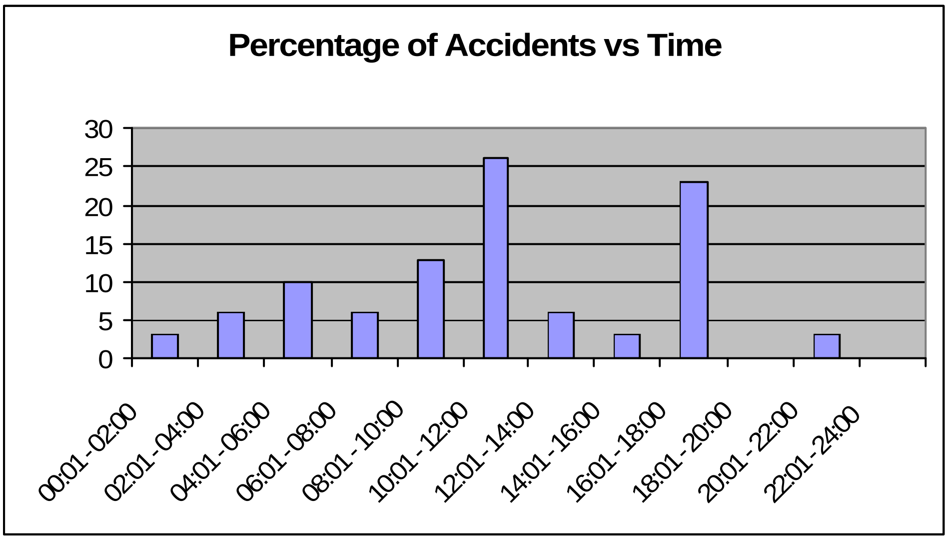

Figure 4: Time distribution of 'injury' accidents involving haul trucks at Mine B

4.3 Field Evaluations

4.3.1 Shift cycles

Shift work is done by two or more groups of workers who alternate their assigned shifts between different times of a given day. The shift schedules at the project mines were organised in a variety of ways. All the mines used rotating shift systems as indicated.

Mine A

A three-shift rotating cycle was in place at this mine (7-1; 7-5; 7-1):

MMMMMMMONNNNNNNOOOOOAAAAAAAO

M = Morning shift (08h00 – 16h00)
A = Afternoon shift (16h00 – 24h00)
N = Night shift (00h00 – 08h00)
O = Day off

The cycle contained forward rotation (morning to night), as well as backward rotation (night to afternoon) elements. Ideally, rotation should be forward (morning to afternoon to night) (Kogi, 2001).

Mine B1

A three-shift forward rotating cycle was in place at this mine (6-1; 6-1; 6-1):

M*MMMMMOAAAAAAON*NNNNNO

M* = Morning shift (08h00 – 14h00) (first day of shift cycle)

M = Morning shift (06h00 – 14h00)

A = Afternoon shift (14h00 – 22h00)

N* = Night shift (00h00 – 08h00) (first day of shift cycle)

N = Night shift (22h00 – 06h00)

O = Day off

Mine B2

Mine B2 was the same mine as Mine B1, but with a changed shift cycle. The three-shift forward rotating cycle was maintained (6-1; 6-1; 6-1), but the shift duration was changed: 9 hours for all the morning shifts, 9 hours for all the afternoon shifts and only 6 hours for all the night shifts.

MMMMMMOAAAAAAONNNNNNO

M = Morning shift (06h00 – 15h00)

A = Afternoon shift (15h00 – 24h00)

N = Night shift (00h00 – 06h00)

O = Day off

Mine C

A three-shift rotating cycle was in place at this mine (7-1; 7-5; 7-1). The cycle contained forward rotation (morning to night), as well as backward (night to afternoon) rotation elements:

MMMMMMMONNNNNNNOOOOOAAAAAAAO

M = Morning shift (07h00 – 15h00)

A = Afternoon shift (15h15 – 23h15)

N = Night shift (23h00 – 07h15)

O = Day off

Mine D

A two-shift forward rotating cycle was in place at this mine (2-1; 2- 4):

DDONNOOOO

D = Day shift (05h30 – 18h00)
N = Night shift (18h00 – 06h00)
O = Day off

Mine D implemented a rapidly rotating system which has certain advantages compared with slow or weekly rotation. Faster rotation tends to disrupt the circadian rhythms to a lesser degree because the original day-work-night–sleep style is resumed before fatigue and sleep deficiencies accumulate.

The design of shift systems is a complex issue because a variety of organisational and social aspects must be taken into account, such as the nature of the work and manning requirements, health and safety requirements, and worker preferences. At all four mines the shift system was negotiated between management and the employees.

The shift rotation at Mines A and D (forward and backward in the same shift schedule) was opposite to the preferable forward rotation (morning to afternoon to night) (Kogi, 2001). Relatively slowly rotating shift systems (6 to 7 days on the same shift) were used at Mines A, B1, B2 and C. In general, the endogenous circadian body clock of most people cannot adjust to night work within one week (Knauth, 1996). This lack of adjustment is reflected in the typical shorter duration of sleep during the day after night shifts, which was also observed in this study (Section 4.3.2). If there are several night shifts in a row, there is likely to be a bigger cumulative sleep deficit towards the end of a span of night shifts (Escriba *et al.*, 1992).

4.3.2 Feedback from questionnaire

From the information obtained from 70 haul-truck operators by means of the questionnaire (Appendix A), it is evident that approximately 75% of the operators live in mine hostels, with the remainder staying in mine villages or on their own property. Most of them use transport (busses) provided by the respective mines to get to work and back. Travelling time to work ranges between 30 and 60 minutes and approximately 20% of the operators found themselves nodding off sometimes during the drive home.

Approximately one in three of the operators reported difficulty in falling asleep and half complained about disturbed sleep. The major reasons given for the disturbed sleep (especially during daytime sleep periods) included extremes of temperature, noise, activities in the hostel (mainly as a result of unsynchronised shift schedules), excessive lighting or sunlight, uncomfortable beds, sleeping on very thin mattresses (less than 5 cm), sharing a room with other workers not on the same shift, and stress/worries. Reported sleeping times ranged between 3 and 9 hours, and the sleeping periods after night shift (3 to 9 hours) were generally shorter and more disturbed than those after morning and afternoon shifts (6 to 9 hours). These findings are consistent with previous observations that shift work, involving daytime sleep periods, is well established as a cause of disturbed and shortened sleep (Åkerstedt, 1998).

At one mine, operators were required to complete an Epworth Sleepiness questionnaire (Question 37 of Appendix A). One quarter of them were diagnosed as being excessively sleepy on the basis of scores that reflected a high chance of dozing off while watching television, for example. Approximately half of the operators classified themselves as moderately morning people; the remainder were intermediate types according to the Horne and Ostberg Morningness/Eveningness Questionnaire, perhaps not the best characteristics to adapt to late work or night work.

Based on the difficulties experienced by operators to understand the questions of the questionnaires, it was decided not to use them at the other project mines. Most of the questions were designed for a typical Westernised population and included items not familiar to the operators.

Approximately 32% of the drivers reported having experienced a potentially dangerous event while driving haul trucks: 21% had nodded off at the wheel, 21% had driven off the road, and 5% had experienced a near-accident due to fatigue. At one mine two operators reported having had an accident because they fell asleep at the wheel.

The most common preventive actions taken by drivers to fight drowsiness are turning on the air conditioner, opening windows, stopping to rest, turning on the radio, reporting to control centre, getting out of the truck, washing their faces, talking to other drivers on the radio, or consuming food or a beverage. Although these techniques provide some relief, the improvement in alertness is only transient, and their effects on driving performance negligible (Brown et al., 1997; Reyner and Horne, 1998).

The reasons given for becoming sleepy at work included too many hours of continuous driving (only one of the project mines has an ‘official’ rest break of between 10 and 30 minutes after approximately 5 - 6 hours of driving), lack of sleep or poor quality of sleep between shifts, monotonous roads, and a hot and stuffy cabin.

Recommendations from operators on the means to improve the situation include:

? short breaks to rest or drink tea or coffee after 5 hours of driving, or between 03h00 and 05h00.

? installing radios in the trucks to alleviate boredom.

? changes to the shift cycle, especially with regard to the number of consecutive shifts,.

? allowing operators to rest when they feel sleepy.

? improving hostel conditions, particularly with regard to the noise problem and sleeping facilities.

As part of the questionnaire, operators were asked to rate their perceived level of sleepiness subjectively at the beginning and end of each shift. The rating of the Wits SleepWake Scale was used and the sleepiness scores obtained from these ratings were analysed using t-tests. Repeated-measure analyses of variance (ANOVA) were used to compare perceived levels of sleepiness. The results of the analyses are given in Figure 5. Mine B1 has been excluded from the analyses because of insufficient data relating to the morning and afternoon shifts. At Mine C, only operators on the day shift and on the night shift agreed to participate in this part of the study.

Mine A (n = 12)

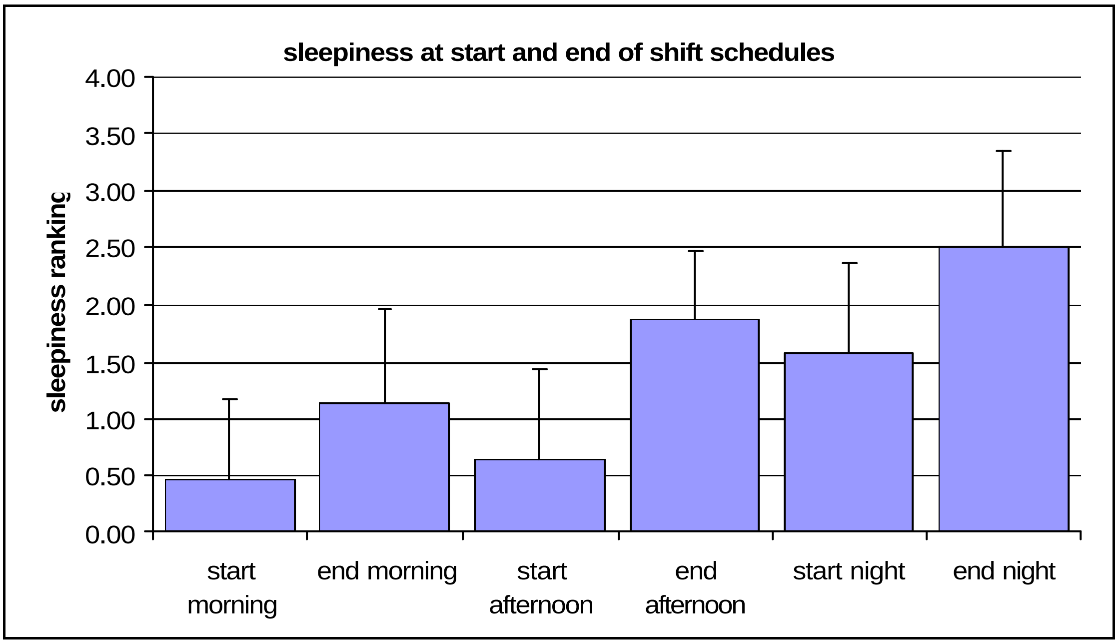

Figure 5: Sleepiness at the start and end of shift schedules (Mine A)

Operators reported being significantly more sleepy at the end of the morning, afternoon and night shifts than at the beginning of each shift (paired t-test, $p <= 0.02$). Sleepiness scores at the start of a night shift were significantly greater than at the start of the morning and afternoon shift ($p < 0.01$). Operators reported being significantly sleepier at the end of a night shift than at the end of a morning shift ($p < 0.01$).

Mine B2 (n = 18)

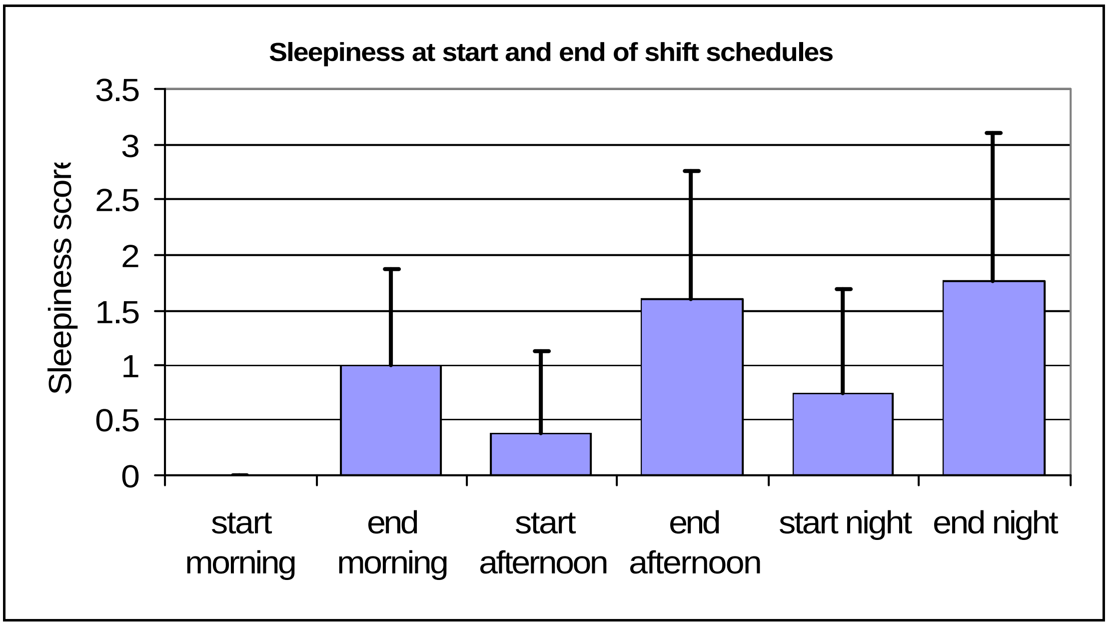

Figure 6: Sleepiness at the start and end of shift schedules (Mine B2)

Sleepiness scores at the end of a morning, afternoon and night shift were significantly greater than at the beginning of each shift (paired t-test, $p <= 0.0003$). Operators are significantly sleepier at the start of a night shift than at the start of a morning shift ($p < 0.01$). Sleepiness at the end of a morning, afternoon and night shift was not significantly different ($p > 0.05$).

Mine C (n = 11)

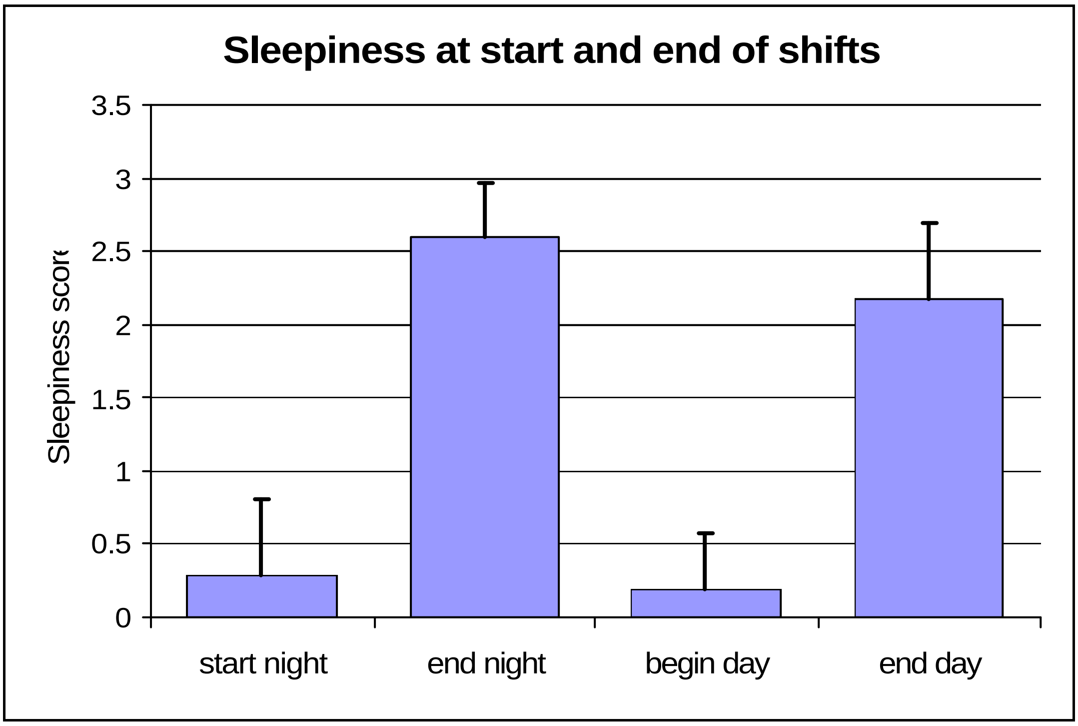

Figure 7: Sleepiness at the start and end of shift schedules (Mine C)

Drivers reported being significantly more sleepy at the end of a night shift than at the beginning of a night shift (paired t-test, p = 0.002). They also reported being significantly more sleepy at the end of a night shift than at the end of a day shift (p = 0.007).

Mine D (n=11)

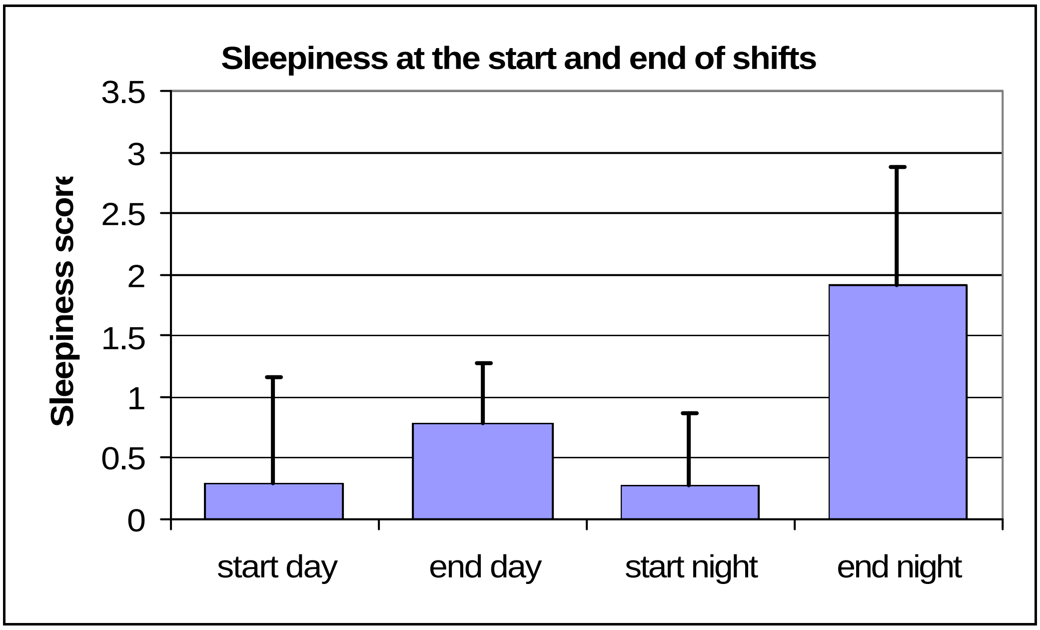

Figure 8: Sleepiness at the start and end of shift schedules (Mine D)

Operators reported being significantly more sleepy at the end of a shift than at the beginning, with regard to both day and night shifts (paired t-test, p < 0.0001). They reported being significantly more sleepy at the end of a night shift than at the end of a day shift, (paired t-test, p = 0.008), even though they were at the same level of alertness at the beginning of each type of shift (p > 0.05).

All Mines

The start and end of night-shift sleepiness levels for all the project mines are compared in Figure 9.

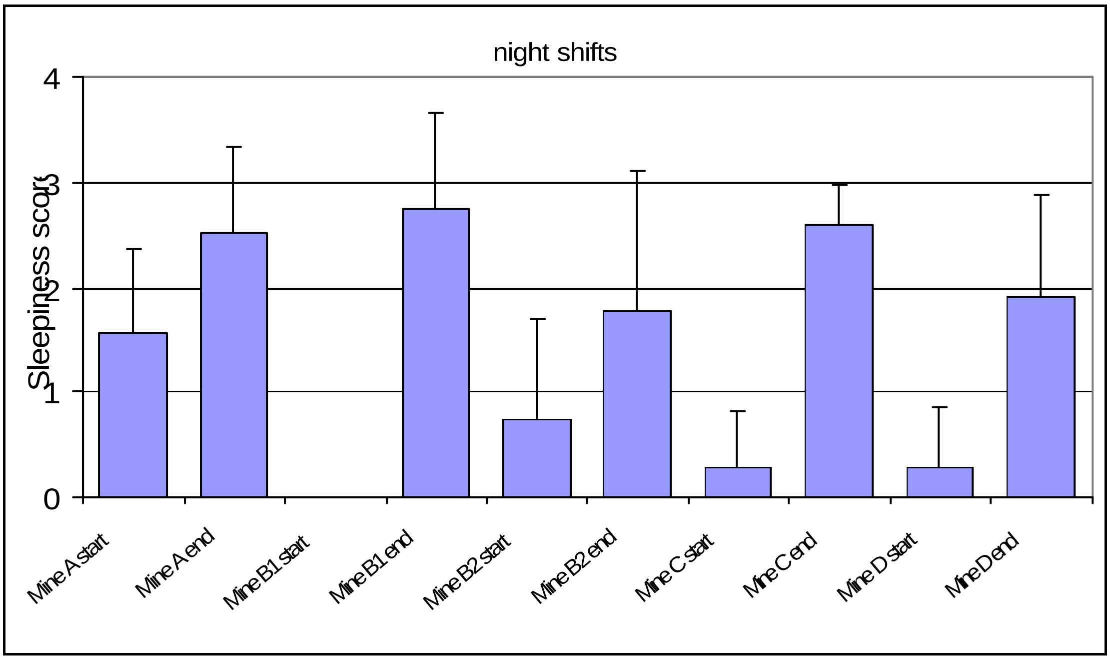

Figure 9: Sleepiness at the start and end of night shifts for all project mines

One-way ANOVAs of the sleepiness levels at the beginning of the night shift suggest that the operators at Mine A were more sleepy than the operators at the other mines ($p < 0.0001$). The operators at Mine B1 were more alert than their counterparts at Mine B2 at the beginning of the night shift ($p < 0.05$).

4.3.3 Sleepiness rating during shift

Every hour, for the duration of a shift, operators marked the face on the Wits SleepWake Scale (Figure 1) that best described how sleepy or alert they felt at that time. Thurstone's scaling procedure was then used to transform the individual rankings to a consolidated interval scale. A score of 0 indicated that the operator was alert and higher scores were indicative of the level of sleepiness experienced.

Mine A

The average sleepiness rankings at Mine A for the morning, afternoon and night shifts are given in Figures 10, 11 and 12. During the morning shift, the highest level of sleepiness on average, was experienced towards the end of the shift. A similar pattern was observed during the afternoon shift, with sleepiness creeping in from 20h00, reaching a peak at 24h00 on completion of the shift. The night shift showed the typical response, with sleepiness levels increasing substantially from 03h00 to 06h00.

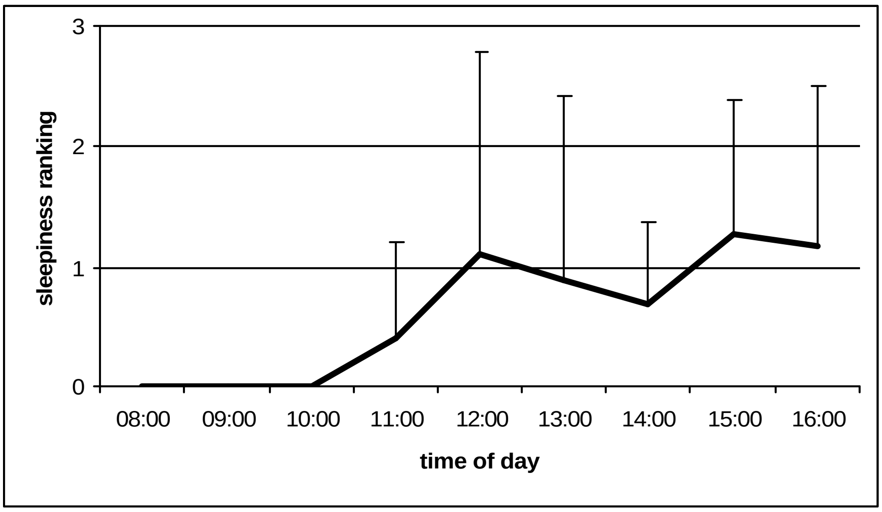

Figure 10: Sleepiness ranking during the morning shift (Mine A)

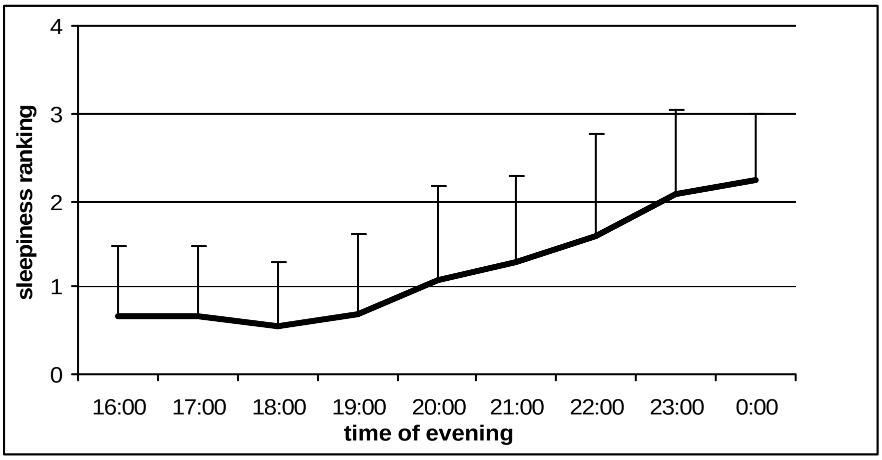

Figure 11: Sleepiness ranking during the afternoon shift (Mine A)

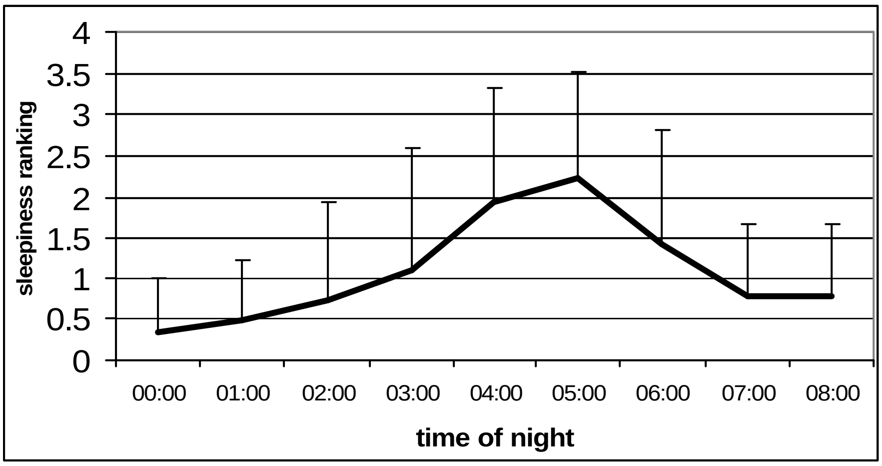

Figure 12: Sleepiness ranking during the night shift (Mine A)

Mine B1

The average sleepiness rankings at Mine B1 for the morning, afternoon and night shifts are given in Figures 13, 14 and 15. The sleepiness levels during the morning shift fluctuated and reached peak values at 08h00 and 10h00. During the afternoon shift, sleepiness levels started to increase from 19h00 onwards, with the highest level of sleepiness recorded towards the end of the shift. The night shift showed the typical response, with sleepiness levels increasing substantially from 02h00, reaching a peak between 03h00 and 04h00, and returning to being alert at the end of the shift at 06h00.

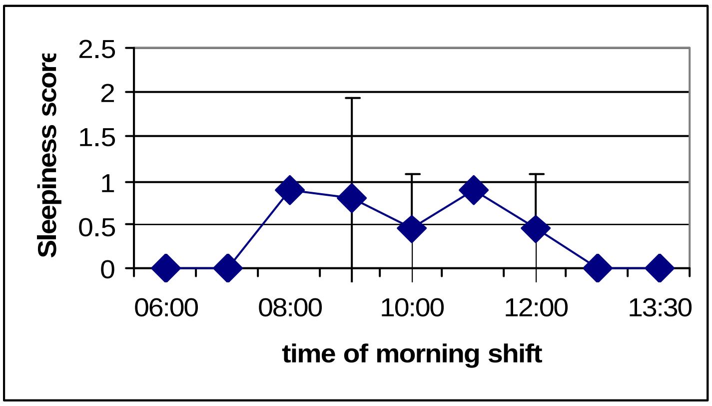

Figure 13: Sleepiness ranking during the morning shift (Mine B1)

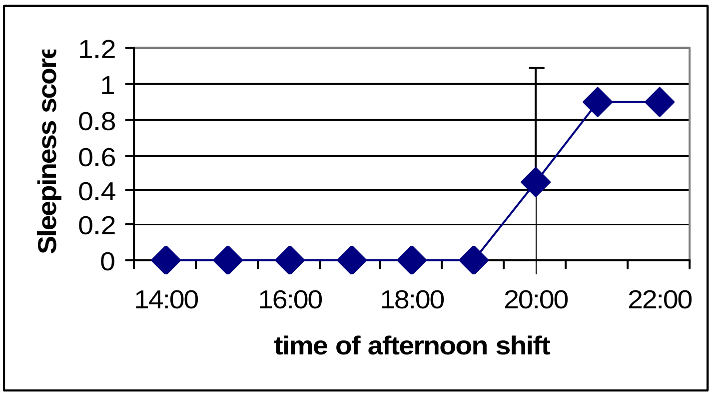

Figure 14: Sleepiness ranking during the afternoon shift (Mine B1)

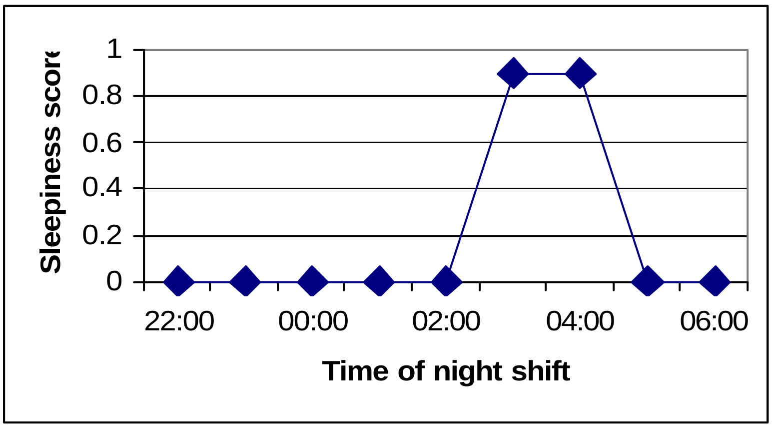

Figure 15: Sleepiness ranking during the night shift (Mine B1)

Mine B2

The average sleepiness rankings at Mine B2 for the morning, afternoon and night shifts are given in Figures 16, 17 and 18. The sleepiness levels during the morning and afternoon shifts reached peak values towards the end of these shifts. During the night shift, which was only 6 hours long, sleepiness levels increased from approximately 04h00 and reached a peak at the end of the shift at 06h00.

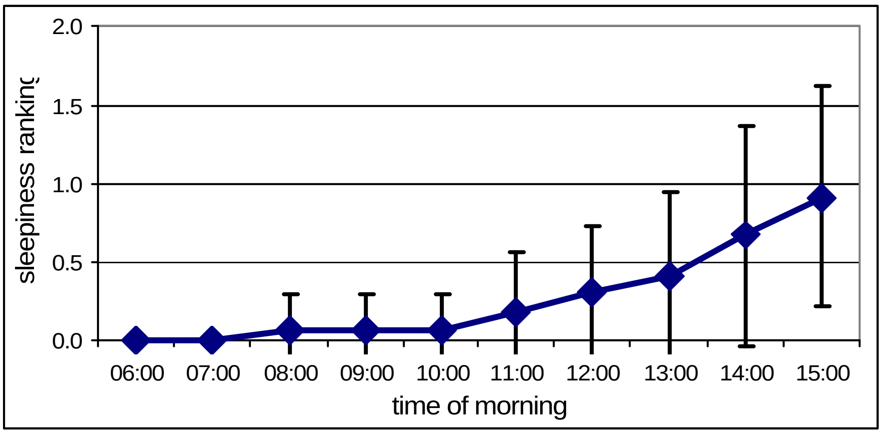

Figure 16: Sleepiness ranking during the morning shift (Mine B2)

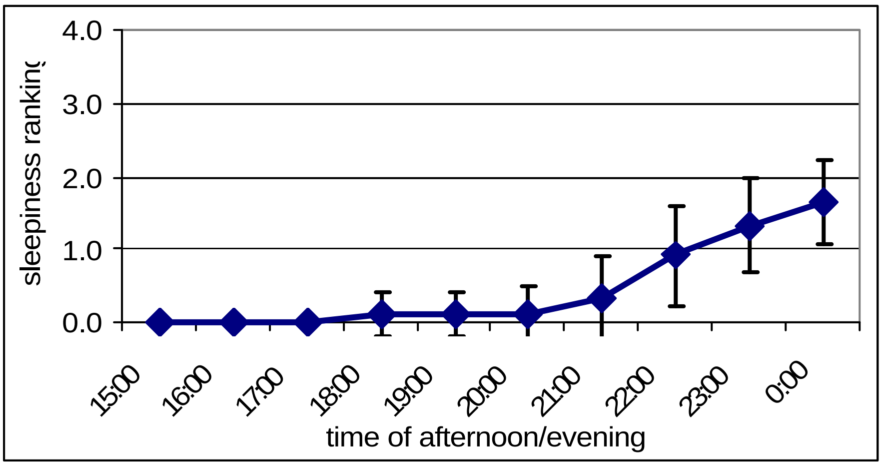

Figure 17: Sleepiness ranking during the afternoon shift (Mine B2)

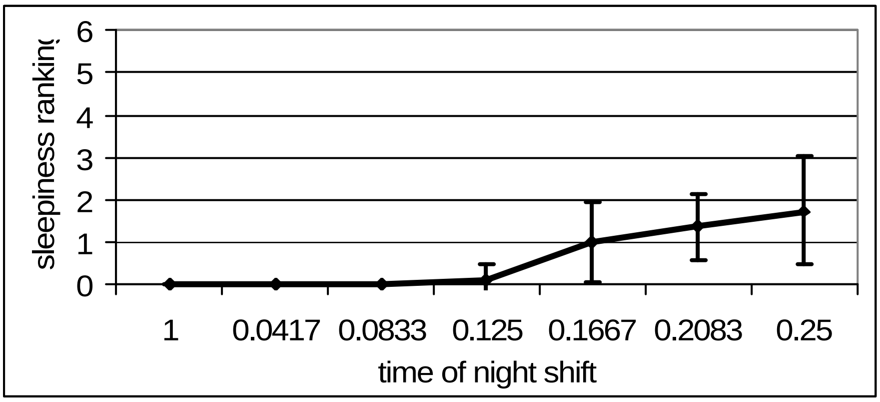

Figure 18: Sleepiness ranking during the night shift (Mine B2)

Mine C

The average sleepiness rankings for the morning and night shifts at Mine C are given in Figures 19 and 20. Workers on the day shift were sleepier at 14h00 than at 07h00 and 08h00. During the night shift, sleepiness peaked at 06h00 compared with the levels at 00h00 and 01h00.

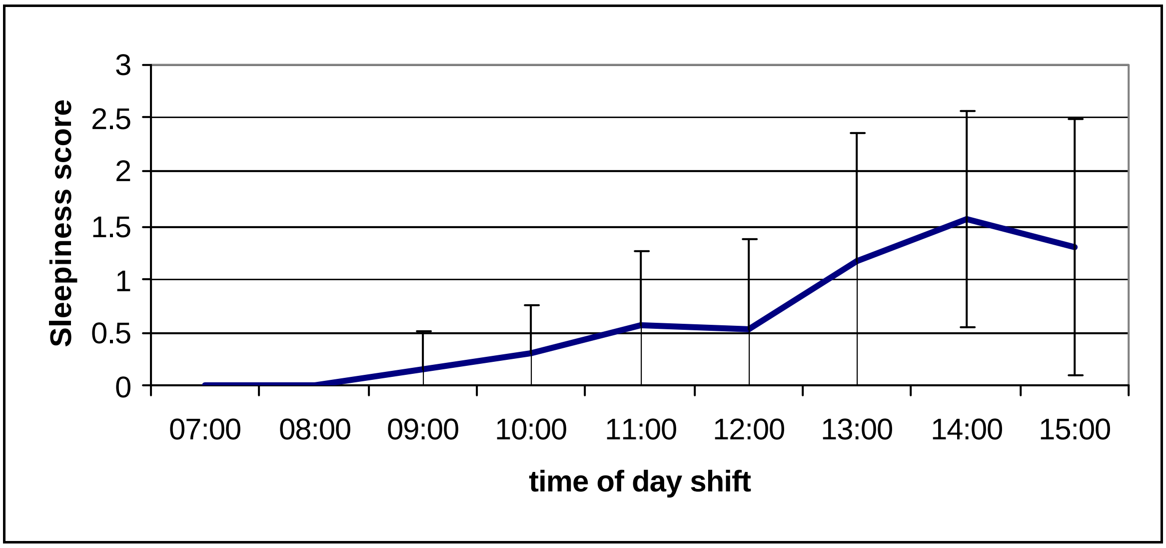

Figure 19: Sleepiness ranking during the morning shift (Mine C)

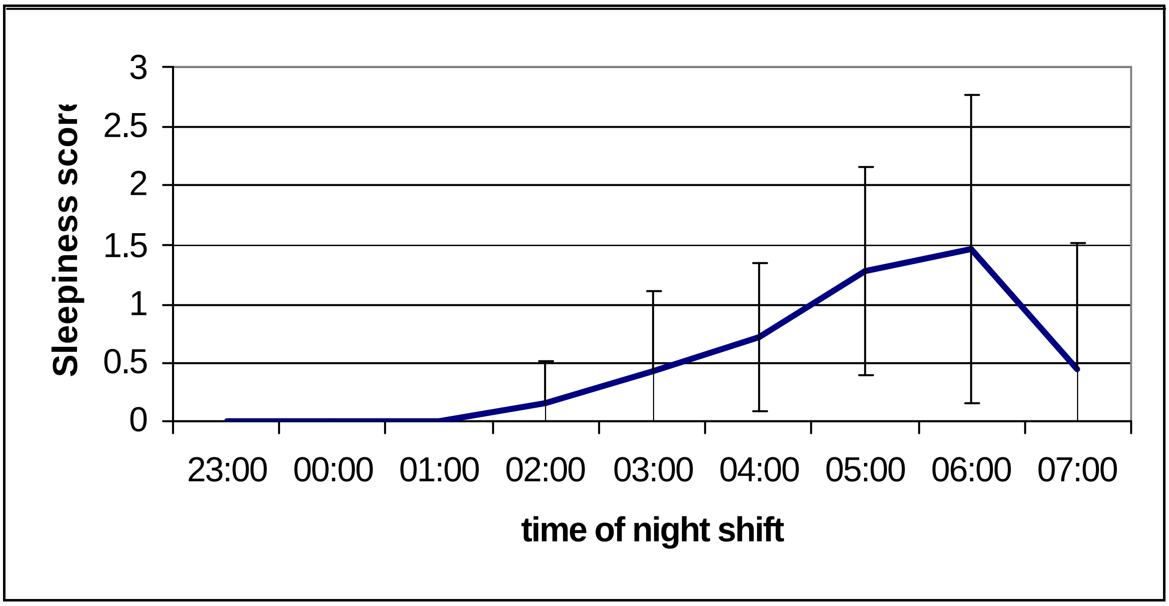

Figure 20: Sleepiness ranking during the night shift (Mine C)

Mine D

Mine D uses a rapidly rotating shift cycle and the average sleepiness ranking for the two consecutive morning shifts and the two consecutive night shifts are given in Figures 21 and 22. There appeared to be an overall increase in sleepiness as the second day shift progressed, which was not apparent on the first day shift. The pattern of sleepiness during the second day shift was nevertheless very similar to that during the first. On the first night shift, drivers became significant sleepier as the shift progressed, such that from 02h00 to 06h00 the drivers were more sleepy than from 18h00 to 21h00, and from 03h00 to 05h00 they were more sleepy than from 22h00 or 23h00. On the second night shift, drivers were more sleepy from 01h00 to 06h00 than from 18h00 to 21h00, and sleepier at 04h00 and 05h00 than at 22h00.

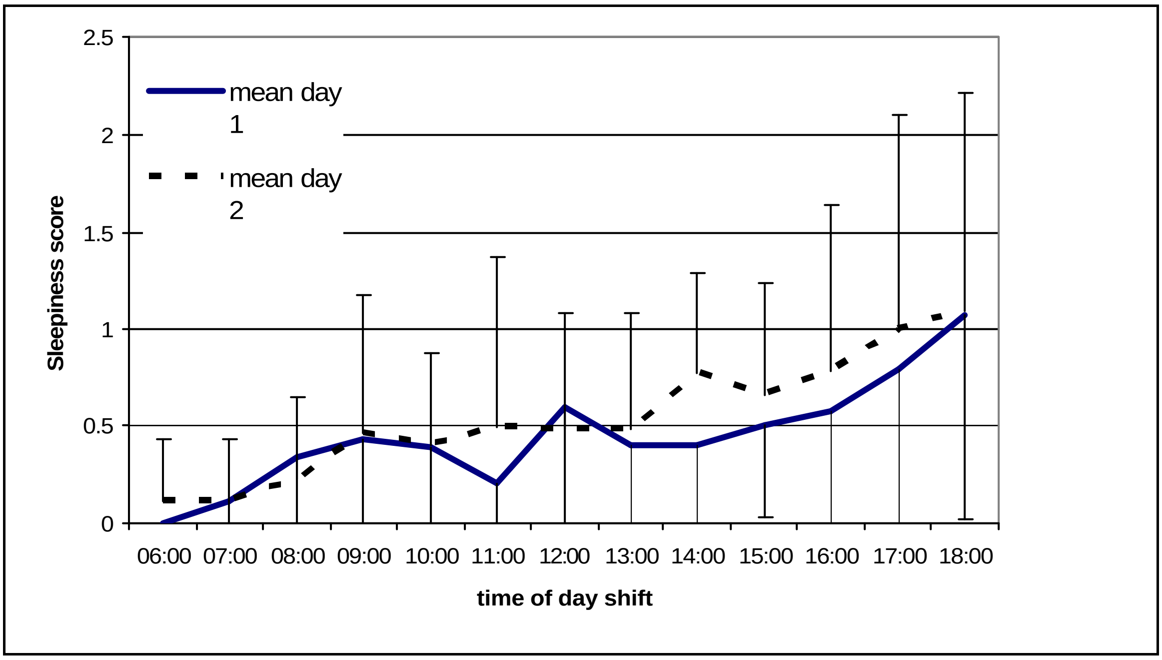

Figure 21: Sleepiness ranking during the day shift (Mine D)

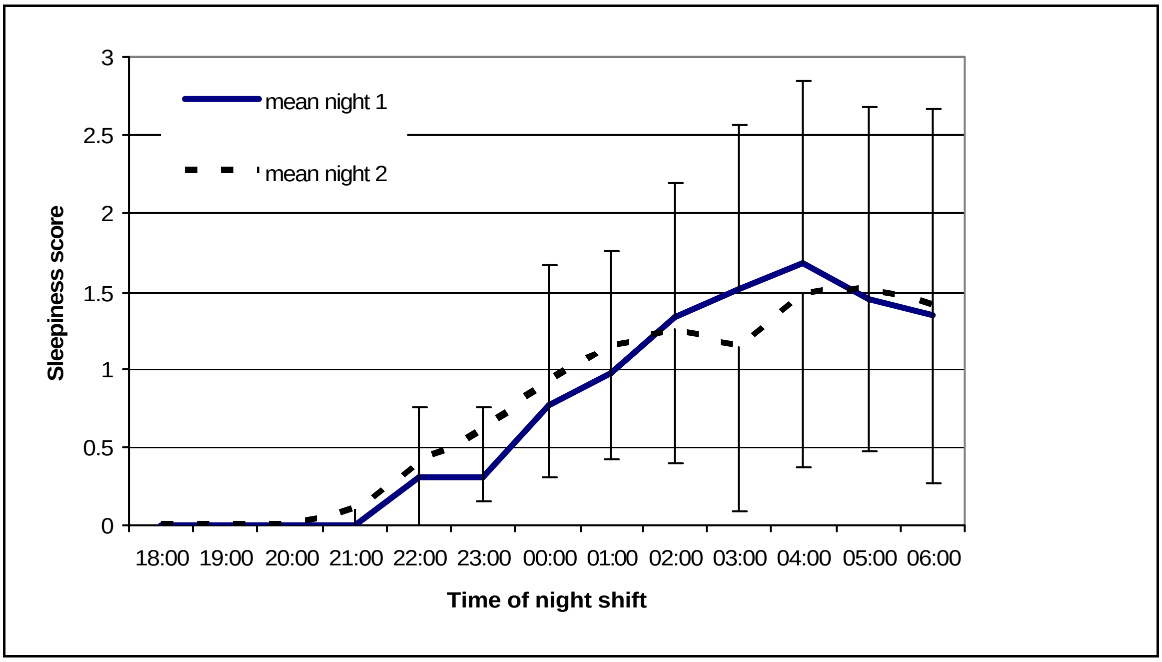

Figure 22: Sleepiness ranking during the night shift (Mine D)

The results obtained on all the mines are in agreement with findings in the literature which suggest that people who go without sleep during the night, and who are not used to night work, experience their greatest feeling of sleepiness not at 02h00 but some hours later, more typically between 04h00 and 06h00 (Horne and Reyner, 2001).

4.3.4 Physical stresses

The thermal conditions inside the cabins of haul trucks (most of them fitted with air conditioners) were recorded and examples of typical recordings are given in Figures 23 and 24. The heat stress levels recorded were considered not to pose any significant risk of extreme heat discomfort nor to be conducive to the development of heat disorders. Supervisors, however, mentioned that some of the operators use the air-conditioner to heat the cabin above these levels, especially on colder days and nights.

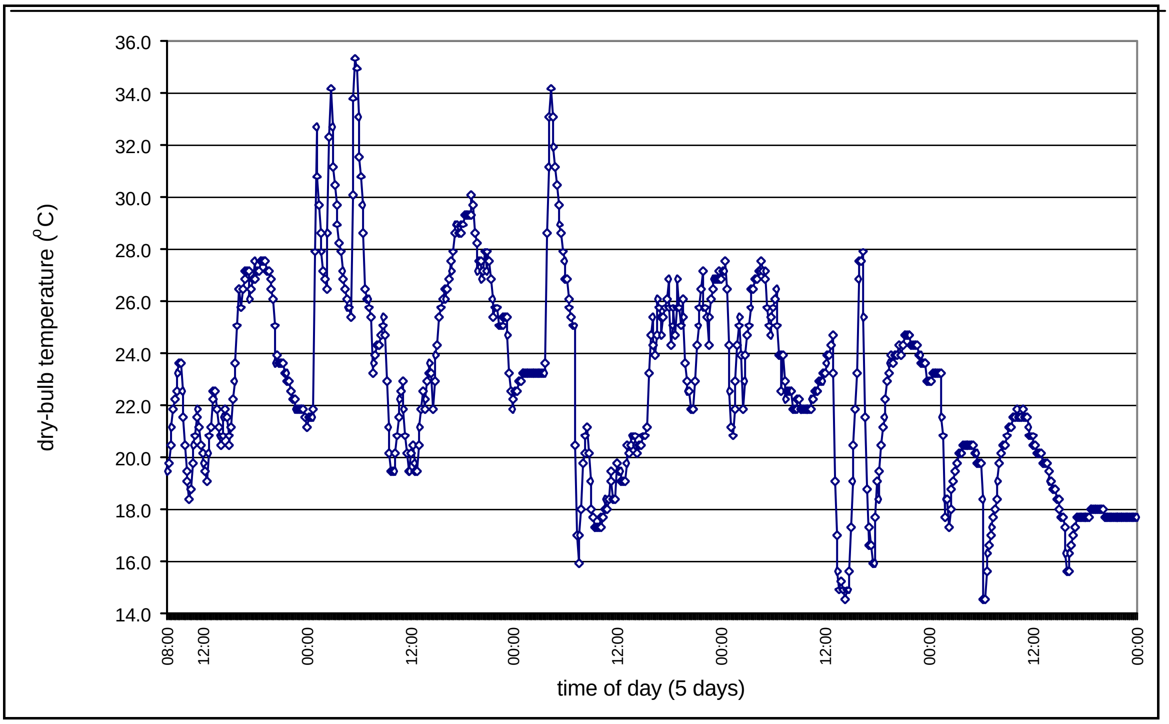

Figure 23: Dry-bulb temperatures measured in cabin of haul truck over a 5-day period – Example 1

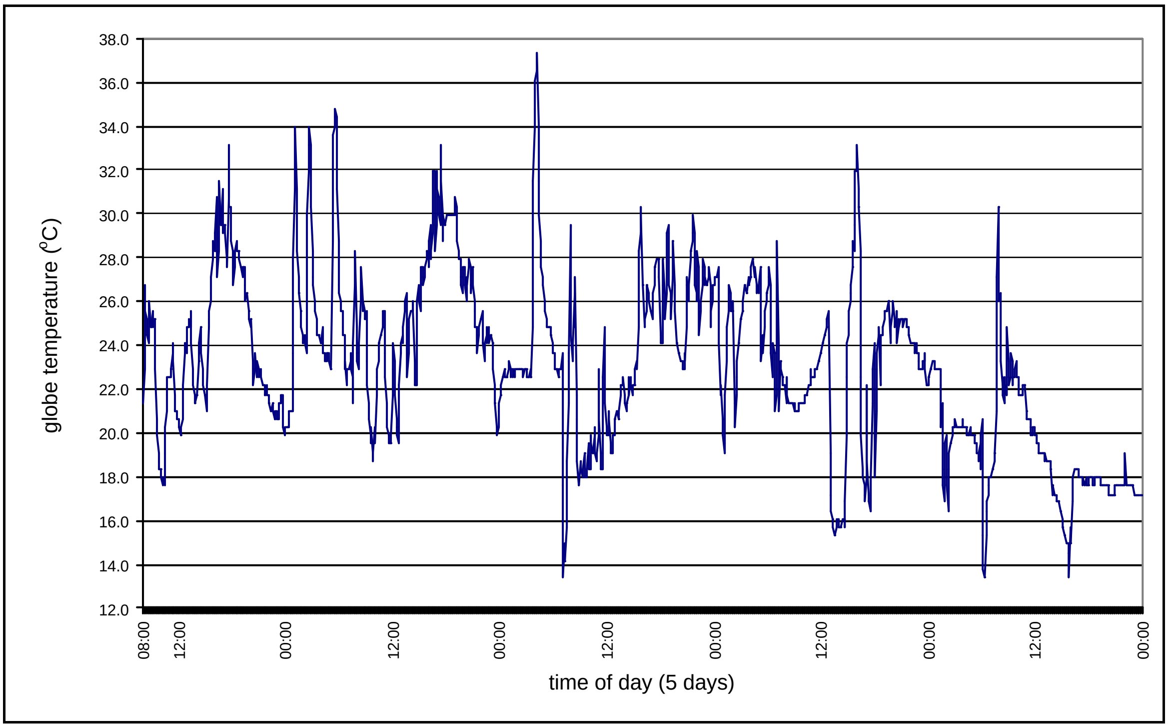

Figure 24: Radiant (globe) temperatures measured in cabin of haul truck over a 5-day period – Example 2

The sound levels recorded in the cabins of haul trucks were surprisingly high (Figure 25) and may potentially pose a risk. This aspect needs further investigation.

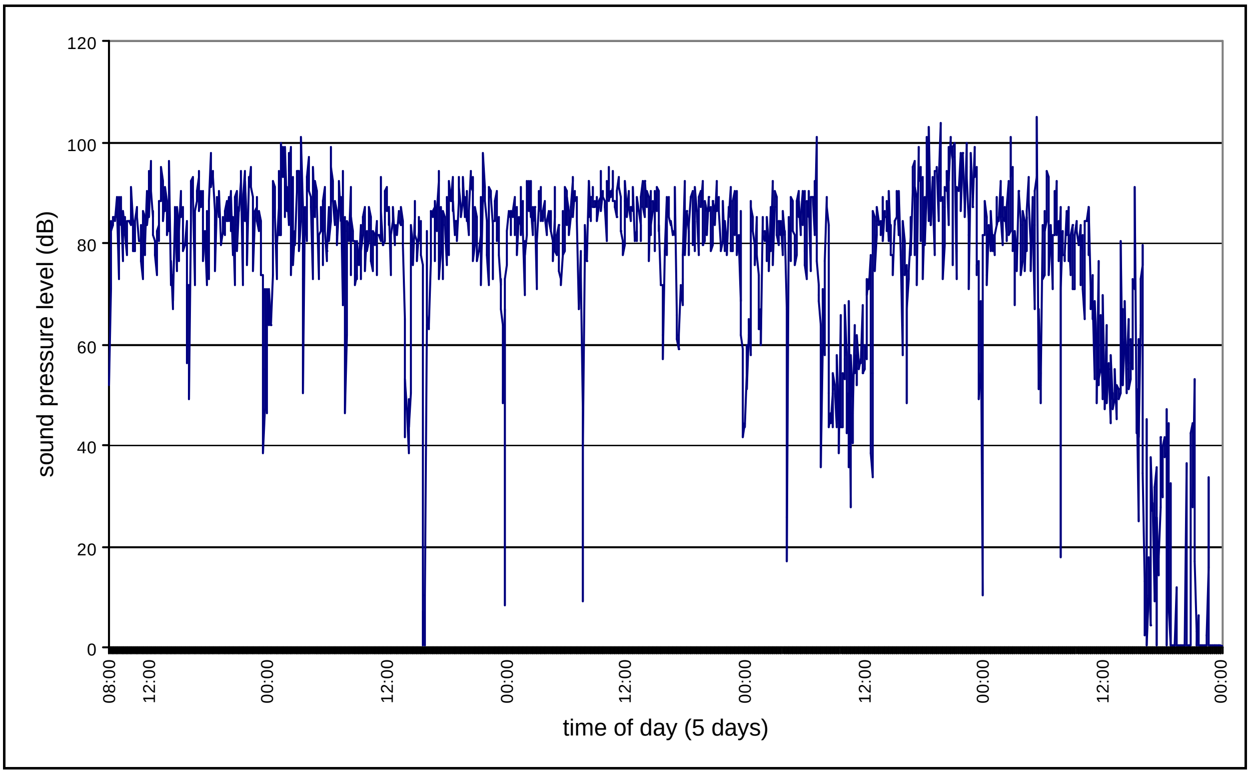

Figure 25: Sound levels measured in cabin of a haul truck over a 5-day period

The concentrations of carbon monoxide and carbon dioxide measured in the cabins of a number of the haul trucks used in the study, seldom exceeded normal background levels and never reached or exceeded occupational exposure limits. Oxygen concentrations in the cabins did not differ from normal ambient concentrations.

From the heart rates recorded during some of the shifts, it is evident that operators were not exposed to undue strain. At one of the project mines, heart rates ranged between 56 and 105 beats per minute during the morning shift, between 73 and 100 beats per minute during the afternoon shift, and between 65 and 98 beats per minute during the night shift. A similar trend was observed at the other mines. Figures 26 and 27 depict typical heart rate profiles of haul truck operators during an afternoon and a night shift.

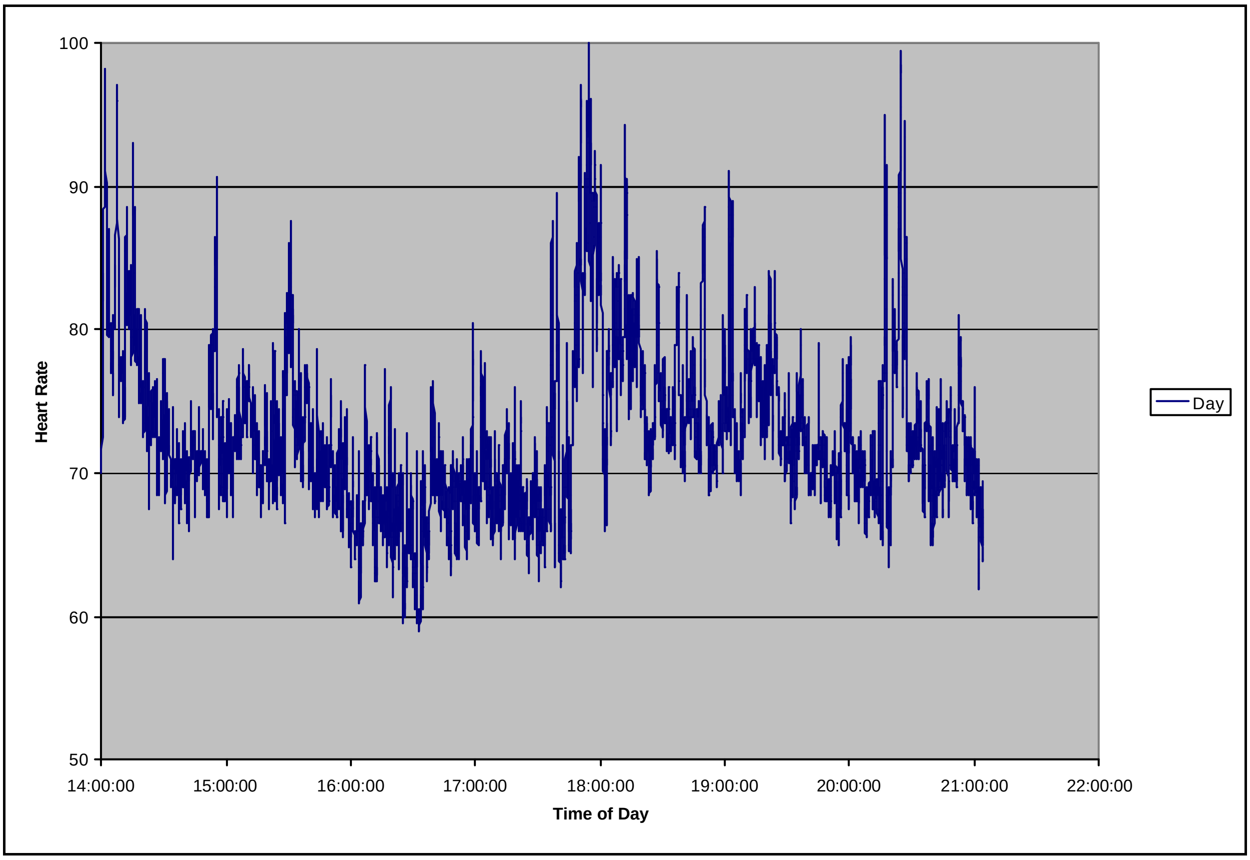

Figure26: Heart rate profile of haul truck operator during an afternoon shift

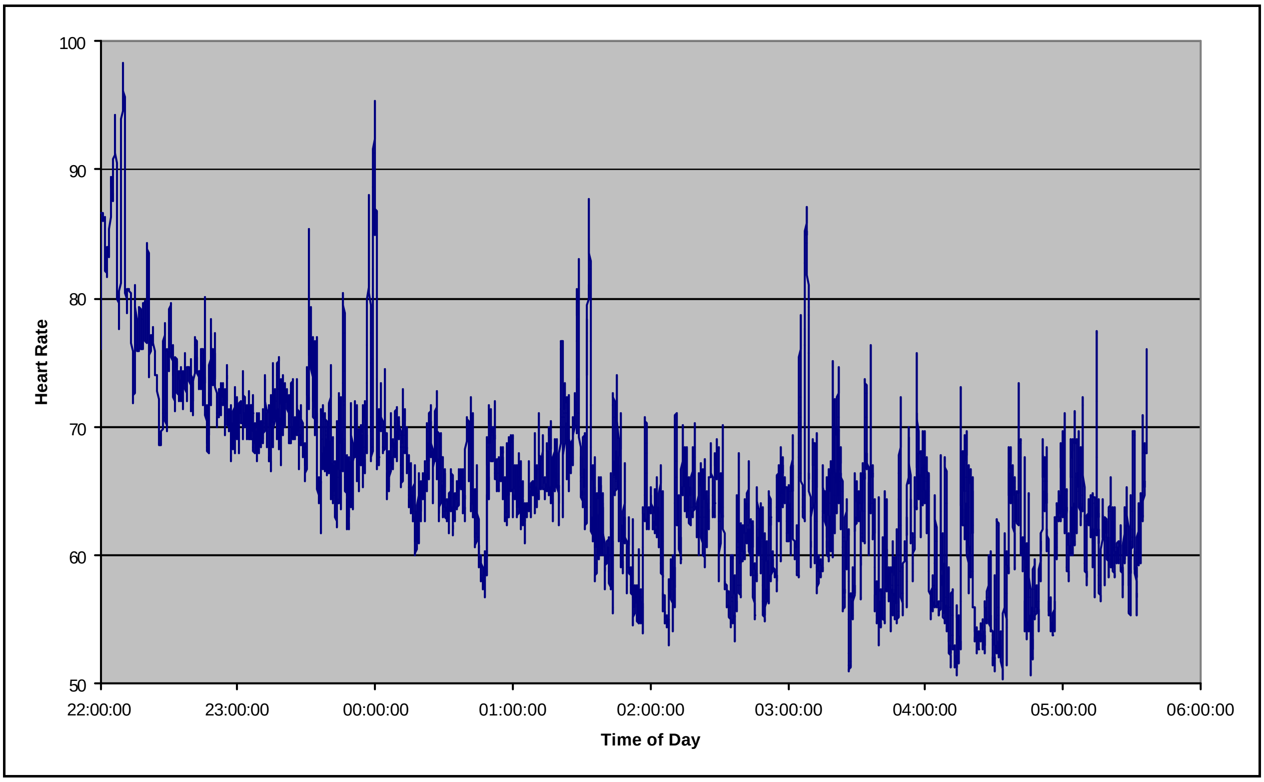

Figure 27: Heart rate profile of haul truck operator during a night shift

5 Summary of risk factors

From the literature and observations made during the field assessments, it appears that the following factors could potentially driver alertness during the operation of haul trucks in the course of mining operations:

? Disruptions in circadian rhythms associated with phase shifting in sleepiness/wakefulness cycles

? Inadequate (shortened) sleep

? Poor quality of sleep between shifts

? Fatigue

? Daytime sleepiness

? Suboptimally designed shift schedules (unusual work schedules)

? Time of day

? Night-shift driving (greater tendency towards drowsiness)

? Extended driving times

? Monotonous nature of tasks

? Certain medical conditions (obstructive sleep-apnoea syndrome, for example) and medications

? Poor awareness of the causes and consequences of fatigue, the importance of sufficient sleep and ways to achieve it

? Lifestyles.

6 Countermeasures

Long, undemanding and monotonous driving is conducive to sleepiness and increases the risk of accidents. Countermeasures that could potentially alleviate sleepiness and enhance alertness in haul truck drivers are given below.

6.1 Well-Designed Shift Work Schedules

Well-designed shift schedules have the potential to alleviate the adverse consequences of sleepiness for workers, particularly during the night shift. An example of this is a unique shift system in place at a Canadian mine (Hossain *et al*., 2003). Introducing a 10-hour night shift that finished at 03h00 resulted in significant benefits in terms of improved sleep and performance.

Designing shift systems is a complex issue and it is important to note that there are no ideal systems that can be simply computed using given criteria. This is because a variety of organisational and social aspects must also be taken into account when designing shift systems. These include production-related matters, manning demands, safety and health issues, social needs and worker preferences.

There are, however, certain key ergonomics-related aspects to be considered when designing shift cycles, including speed and direction of shift rotation, duration of shifts, timing of shifts and intervals between shifts – all factors influencing both physiological adjustments and the social life of shift workers (Rosa and Colligan, 1997, Queensland Government, 2001).

It is generally recommended that shift scheduling should follow a clockwise (morning, afternoon, and night) rotation, rather than a counterclockwise (morning, night, afternoon) rotation because the former is less disruptive to the circadian rhythm. An isolated night shift is easier for some workers because there is no resetting of the circadian rhythms. Short strings of night shifts should not exceed three nights, thus resulting in less accumulation of sleep deficit. For shift workers who have to work a variety of shifts, it is better to change shifts rapidly rather than to work long strings of the same shifts. A slowly rotating schedule (e.g. over 3 weeks) allows for better adaptation to working during the night but results in the build-up of sleep debt. An early start to the morning shift usually reduces the length of sleep before the shift, with a concomitant increase in fatigue during the morning shift. Quick changeovers (e.g. from night shift to afternoon shift on the same day) should be avoided, while the number of consecutive shifts should be limited to between five and seven. An example of a checklist to assess fatigue impairment

6.2 Rest Days

The speed of recovery after a week of work is apparently assumed to be one to two days since custom and legislation in many countries prescribe two days off after five days of work. One could also assume that long shifts, night work or early morning work would demand a longer recuperation time. Totterdell and his co-workers (1995) have shown that that one day off is insufficient for shift-working nurses and that often three days may be required. Using experimental night work, Knauth *et al.* (1978) showed that it took two days for the body temperature rhythm to readjust after two night shifts, but three to four days after 21 night shifts. Åkerstedt *et al*. (2000) showed that for those who work long shifts in long sequences, three days are needed for normalisation, whereas 12-h shifts in two to three day sequences seem not to cause accumulated fatigue. They concluded that one day of recovery is never sufficient, two days usually are, whereas three to four days are necessary after periods of severely disturbed circadian rhythmicity. Interestingly, fatigue/sleepiness is often at its peak during the first day of recovery – not on the last day of the working week.

Backward rotating shift schedules seem to cause accumulation of fatigue which further affect workers during their days off. Allowing adequate time to recover from night shifts is necessary because sleep and alertness are significantly impaired for at least three days after a sudden 12-hour shift of the sleep-wake cycle (Kuhn, 2001).

6.3 Structured Breaks During The Shift

Breaks may be seen as a form of recuperation and increased alertness could be expected after breaks. However, breaks are unlikely to have effects on sleepiness induced by circadian or homeostatic factors: breaks should be reserved for countering sleepiness due to time on the task, for example, because the effects of breaks are temporary (Åckerstedt and Landström, 1998). A general guideline in the trucking industry in Australia is at least 30 min of rest after every 5.5 hr driving. An example of a checklist to assess fatigue impairment is given in Appendix B.

6.4 Sleep Management

Sleep management is crucial. The sleeping environment is equally important; it should be dark and quiet so that sleep is not interrupted, especially in the case of night-shift workers who are attempting to sleep out of phase with their intrinsic circadian sleep-wake rhythms.

There is a controversy about whether an average daily sleep quota of 7.5 hours is enough, and whether alertness and performance can be improved by sleeping longer. A 7-8 hour sleep period is considered to be normal and extending sleep by 2-3 hours beyond the norm produces only marginal benefits for an average individual (Ferrera and De Gennaro, 2001).

Napping, when its timing and duration are designed properly, can play an important role in managing shiftwork problems. Napping has been shown to be an effective countermeasure to the deterioration of alertness and performance associated with night work. Naps can be divided into two broad categories, prophylactic and recuperative, on the basis of whether napping occurs before or during/after a work period. Prophylactic naps are taken before sleep loss is incurred, while recuperative or replacement naps are taken after varying amounts of sleep loss (Macchi *et al*., 2002).

Some companies allow workers to take brief naps to boost their alertness and performance. For example, drivers in an oilfield company are not only permitted to nap when they are tired, but are also educated on when and how they should nap (Coburn and Sirois, 1999). Specifically, the drivers are advised to take a nap in a safe area for 15-25 minutes, the instruction being individualised for each driver. The number of vehicular accidents caused by these drivers decreased by 30% with the institution of the comprehensive programme for fatigue reduction, which included appropriate napping strategies.

Shift workers who are not permitted to take a nap during a night shift are often advised to take a nap *before* the shift, the so-called prophylactic nap. The prophylactic nap reduces sleep pressure resulting from being awake for an extended of time before going to work, thereby attenuating potential decrements in alertness and performance during the shift. Where it is difficult to take prophylactic naps, naps taken during the midafternoon may help workers to be alert during the subsequent night shift (Takahashi, 2002). A study by Macchi and co-workers (2002) demonstrated that a 3-h napping opportunity in the afternoon, ending at 17h00 prior to a night shift, has beneficial effects on performance and on subjective and physiological measures of alertness measured up to 14 hours later.

6.5 Health Screening and Counselling

Occupational drivers should be screened regularly for disorders that can contribute to excessive sleepiness. It is estimated that approximately 10% of the general population have a sleep disorder, predominantly insomnia or obstructive sleep apnoea.

Before they are assigned to shift or night work, and especially during the first months of assignment, employees need guidelines on how to cope with this type of work. Workers must be aware of possible difficulties they may experience during the adaptation process, and must be informed about possible health risks.

6.6 Educational Programmes

The best insight a driver has into his or her sleepiness comes from his or her own self-awareness of it. What many drivers fail to realise is that sleepiness portends sleep, which can occur more rapidly than they realise, especially when the driver has reached the more profound stages of fighting off sleep (evidenced by e.g. opening the vehicle's window, turning up the radio, frequent moving around in the driver's seat), and they need to realise that these are signs that they are getting very sleepy.

Educating drivers in 'sleep hygiene' could contribute significantly towards greater awareness of the causes and consequences of fatigue. Sleep times (when and for how long), sleep strategies for different shifts, and the use of medication and stimulants during shift work should form part of the education programme.

If the intention is to change shift workers' behaviour, educational programmes are required and not simply the dissemination of information. Employees should be provided with information on shiftwork including:

? the hazards associated with shiftwork,

? potential safety and health impacts of shiftwork,

? the identification of potential and/or existing problems associated with lack of sleep and fatigue,

- individual coping strategies to best minimise the adverse impacts of shiftwork,
- services available to assist workers to cope with shiftwork
- the effects of diet and exercise to cope with shiftwork, and
- the effects of drugs and alcohol to cope with shiftwork.

6.7 Food and Fluid Intake

Research on the effect of food intake on the degree of alertness is rather limited and most knowledge is speculative. Timing of food intake, rather than the content of the diet, has been shown to assist in the transition to a new light-dark cycle, but its effect is minimal at best (Comperatore and Krueger, 1990). Positive effects of food breaks on driver performance have been shown and the results of a study by Hubert (1972) showed that the risk of falling asleep was reduced by an increased sugar intake. Heavy food intake can lead to an increased risk of sleepiness.

As expected, positive effects on alertness and performance have been observed after the intake of caffeine, and coffee is often used as a countermeasure to driver sleepiness. Caffeine blocks brain adenosine receptors, and as adenosine is thought to be a potent sleep promoter, caffeine may well have a direct effect on this aspect of the sleep system. There are also routes by which caffeine can act on alertness, for example, through its effects on the synthesis and turnover of catecholamines (Battig and Welzl, 1993). Research outside the field of driving has shown that about 150-200 mg of caffeine significantly improves alertness in sleepy people.

Moderate doses, ranging from 2-4 mg/kg will cause a significant alerting effect (Meulbach and Walsh, 1995). (One cup of coffee contains approximately 100 mg caffeine.) The effect will persist for 5 to 6 hours after the administration. On the other hand, if sleep deprivation is longer than 24 hours, the use of caffeine would seem less appropriate, since considerably higher doses (6-9 mg/kg) would be required (Penatar and Thorne, 1990), which would cause side-effects (trembling, jitteriness, etc).

In a study to investigate the effectiveness of a well-known ‘functional energy drink’ in reducing sleepiness in drivers, it was found that the energy drink was beneficial in reducing sleepiness and sleep-related driving incidents, particularly during the first 90 minutes of the drive. Findings also suggest that the energy drink, containing 80 mg caffeine and other ingredients such as taurine, sucrose, glucose and vitamin B complex, is more effective than coffee with the same amount of caffeine (Reyner and Horne, 2002)

6.8 Devices for Measuring Driver's Wakefulness

A number of devices have been developed that monitor the physiological status of the driver and detect the moment when he or she becomes sleepy.

The operation of the 'Sleep Detector' is based on the monitoring of the driver's eye status using the effect that a pupil absorbs more infrared (IR) spectrum light than does skin. The difference in the amount of IR energy reflected by an open and closed eye is detected, the signal is processed and, in the case of the driver closing his or her eye for a period longer than 2 seconds, a warning signal is generated to wake the driver and an alarm is sent to a dispatcher.

The US Federal Highway Administration has shown the drowsiness metric referred to as PERCLOS (the percentage of eyelid closure over time) to be the most effective measure for correlating a driver's attention and lapses in reaction time. Head nodding was chosen as a second useful measure due to the widespread tendency to loose control of one's head pose when falling asleep in a sitting position.

This has led to the design of the 'Copilot', which is a second-generation PERCLOS monitor. The Copilot consists of a digital camera integrated with a digital signal processor and is basically a video-based system for measuring eye closure. The Copilot is designed to be mounted on the dashboard near the steering wheel and the integral driver interface includes a visual gauge and an audible advisory tone.

A capacitive sensor head-motion detector, which uses a collection of head position features over different time intervals, is also under development and is considered to be a more robust method of detecting drowsiness, compared with the currently available technologies such as PERCLOS.

The potential dangers of driving motivate most sleepy drivers to put much effort into remaining awake. The sleepy driver fighting sleep exhibits different durations and sequences of the physiological events that precede sleep onset (Horne and Reyner, 1995). Hence, the various physiological measures that can be used to measure falling asleep can show poor associations with each other, even under the best laboratory conditions. This is a problem that besets the development of physiological monitoring devices for detecting driver sleepiness.

The above findings throw further doubt on the effectiveness of any device for detecting sleepiness that depends on eye closure or blinking rates. Although the classic signs of sleepiness are obvious, those of sleep onset itself are not simple matters to detect in the driver, as the electroencephalogram often reflects a condition of being neither awake nor asleep, with the driver being in a protracted state of quasi-sleep. Even closing of the eyes, which occurs during the normal process of falling asleep, can be delayed to the point where individuals can be asleep with their eyes open. Horne and Reyner (1999) have found eye closing to be an unreliable indicator as, for example, blinking in the driver is also affected by road lighting, oncoming headlights and the in-vehicle temperature. Of greater concern is that drivers may depend too heavily on unreliable devices, to the extent they take greater risks in driving whilst sleepy.

The measurement of a driver's reaction time to pushing a button on the steering wheel in reaction to a randomly generated sound from within the vehicle has been studied as a potential device for monitoring driver sleepiness. This work is still in progress as it requires further investigation, and it cannot be said with any confidence that a reaction time fatigue monitor could be made both effective and reliable. Other investigators (Mackie and Wylie, 1991) advocate caution about such methods as they could be used by the sleepy driver as a form of 'entertainment' to relieve the monotony and distract him or her from the driving.

Other test methods and procedures, most of them still in development phases, include the following:

? Electroencephalographic techniques, including measures of the electroencephalogram, electro-oculogram and electromyogram, or any combination of these. The electroencephalograph (EEG) has been hailed as one of the most successful monitors, utilising alpha, beta and theta waves to reflect the stages from fully alert through to the various stages of sleep. EEG's, however, are not very practical for in-vehicle use due to the need to attach electrodes to several areas of the cranium. There are some devices under development, which do not require electrodes to measure the brain waves. One such device is the 'Mind Switch', under development at the University of Sydney which utilises a headband to monitor brainwaves (Scullion, 1998). However, it will be some time before a prototype is ready and the validity of the device can be ascertained.

? Visually evoked potentials can also be used as a measure of fatigue. These measure the time it takes for a visual stimulus to reach the occipital lobe of the brain, and also involve the attachment of electrodes, dedicated equipment and specialised personnel.

? Heart rate variability also can be used as a measure of fatigue and as a measure of the effort required to perform a task.

Fitness for duty tests have become increasingly popular in the mining industry, as these tests have the potential to detect impairment from a loss of sleep or through the intake of alcohol or other drugs. The TOPS system has been used by traffic and public safety officers in the State of Arizona to determine if a driver is too incapacitated by fatigue to continue (Charlton & Ashton, 1998). The authors state that that failure on the test is justification for removing a driver from the driving task, and as yet, the regulatory use of the system has not been challenged in court.

Anecdotal evidence has suggested that some operators report for the start of a shift with a sleep debt already accrued. Fitness for duty testing would have a place in these circumstances, as the tests are known to detect impairment from both fatigue and alcohol consumption. Five Australian mines are currently using the OSPAT test (a computer-based psychomotor performance test), including the BHP Blackwater and BHP Goonyella Riverside open-cut mines (Mabbott et al., 1999). The manufacturers of the OSPAT system are currently developing divided attention tasks within the test to portray the more complex tasks undertaken in mining operations. Used alone, fitness for duty testing has the potential to reduce the occurrence of potential fatigue-related incidents. Used in conjunction with a fatigue monitoring device, the benefits would be far greater.
Other test procedures at present being developed and standardised to assess fitness for duty include the following:

? The 'critical flicker fusion test', which measures the frequency at the point of discrimination when two light pulses appear to become one. This test is performed using a strobic light.

- The 'Vienna test battery', which uses lights and reaction times to depress buttons and is based on the premise that when fatigued, a driver's reaction time is increased. Reaction times can, however, be improved by mobilising additional effort, even in situations of sleepiness. Therefore, a measure of effort, for example the heart rate, could be used to assess the effect of needing to mobilise additional effort if one is sleepy but still able to perform.

- The modified 'Trail-Making Test', which measures response time. It is a simple tool for assessing impairment involving higher executive functions using visuo-spacial organisation and viso-motor processing speeds.

6.9 Environmental Stimulation

It has been found that alertness in sleep-deprived individuals could be induced through a combination of four different tones with the frequencies 3 050, 3 700, 5 800, and 10 750 Hz at 45 dB (Åkerstedt and Landström, 1998). The results obtained showed strongly improved subject alertness and the feasibility of having such a system installed in vehicles is being investigated.

Several studies have demonstrated decreased subjective sleepiness when bright light is used in the workplace during night shifts. The intensity of lights used in the study was varied between 1 000 and 6 000 lux (Dawson and Campbell, 1991).

7 Conclusions

Shiftwork is often associated with disruptions to normal sleep routines. This is the case especially with night shifts, where the major difficulty is getting undisturbed sleep during the day, particularly in hot climates and noisy environments. The cumulative effect of these disruptions is insufficient recovery sleep, commonly known as sleep debt, leading to increased fatigue. Human fatigue is multifactorial and is usually associated with reduced levels of alertness, concentration gaps and a high risk of motor and cognitive errors. This is also the case with haul truck operators in the South African mining industry: sleepiness and reduced levels of alertness during their operations are realities and potential safety risks.

8 Recommendations

Poor quality and quantity of sleep have been identified as major risk factors in reduced driver alertness during the operation of haul trucks in the course of mining operations. It is therefore recommended that interventions and countermeasures be focused on addressing these problems as a matter of priority.

Managing sleep and work schedules is of critical importance and will require participatory planning and implementation. The countermeasures outlined in Section 6 could form the basis for a site-specific strategy to reduce driver sleepiness.

It is also recommended that SAMRASS be extended to accommodate more detailed analysis of the probable causes and circumstances surrounding accidents. This will significantly increase the potential for using SAMRASS as an important tool in devising accident-prevention strategies.

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Appendix A

Factors affecting driver alertness / sleepiness during the operation of haul trucks

CODE: (shift #) __________ Date:_________________

Time: __________________ Location: ______________

Please answer all the questions, in order, as honestly as possible.

WORK INFORMATION:

1. How do you get to work? (please circle)

lift / own transport / public transport / taxi

2. How many minutes does it take you to get to work from home?

_______________ minutes

3. Do you feel that you are falling asleep on your way to or from work? (please circle)

never seldom sometimes often always

4. For how many years have you been employed as a shift worker at this mine?

_________ years.

5. How many hours per week do you usually **work** (including driving, other work duties, or overtime)? ________ hours

6. **In one day**, how many hours do you usually **drive** a truck for?

________hours

7. In a normal month, how much time off work do you get? (i.e. not working or at home)

_________days

8. Do you have any other job, besides at the mine? (please circle)

yes / no

If yes, how many hours per week do you work at this other job?

______________ hours/week

SOCIAL DATA:

9. Where do you live? (please circle)

free-standing house / flat / mine hostel / mine village / informal settlement /

other, please specify __________

10. Where do you sleep? (please circle)

mattress / bed / floor / sofa /

other, please specify _________________

11. How many people share your bed? (please circle)

none / one / more than one

12. How many people share your room? (please circle)

none / one / more than one

13. How many children are still living at home and dependent on you?

_____________ dependent children

14. On average, how does the health of your children vary over a week?

no health problems / some health problems /

health problems often

15. How many cigarettes do you smoke per day? ____________

16. On average, how many units of alcohol do you consume per day

(1 unit = 1 beer or 1 glass of wine or 1 tot of spirits)

on days that you work: ____________________ ____________________

on days that you don't work: ____________________ ____________________

17. Do you drink caffeinated beverages **to help you stay awake**, for example coffee, tea, cola drinks?

always often sometimes seldom

never

On average how many cups combined do you drink per day? ______________cups/day

18. Please make a mark on the line below to indicate the **quality of your sleep during your time off**?

best sleep

worst sleep

SLEEP HABITS:

19. Do you have any sleep problems, for example, insomnia, restless sleep? (please circle) yes / no

If yes, briefly explain your sleep problem? ______________________________________

____

20. Does your wife / girl friend / bed partner complain about your sleep?

yes / no

If yes, what is the complaint?

____

21. Do you snore? (please circle)

always / often / sometimes / seldom / never / don't know

22. Do you stop breathing when you sleep, or wake up gasping for breath? (please circle)

always / often / sometimes / seldom / never / don't know

23. On average **during a period off work**, for example during the weekend, how many hours do you sleep every

24-hours? ___________ hours/day

For the questions below, please circle the letter or number which best fits your answer

During a normal working week:

24. When you are tired or sleepy during your work time, is it because of:

a. disturbed sleep?	always	/	often	/	sometimes	/	seldom	/	never
b. not enough sleep?	always	/	often	/	sometimes	/	seldom	/	never
c. stress/worries?	always	/	often	/	sometimes	/	seldom	/	never
d. poor health?	always	/	often	/	sometimes	/	seldom	/	never

25. When you feel sleepy behind the wheel, do you........ (more than 1 answer possible)

A) carry on driving as you are

B) carry on driving and
- i. turn on the radio, or make it louder
- ii. talk or sing
- iii. move your body
- iv. open a window
- v. turn on the air conditioner
- vi. smoke a cigarette
- vii. eat
- viii. take a tablet /pill/drug, please specify ___________

C) stop driving and
- i. have a drink, how long do you stop for ___________
- ii.exercise, how long do you stop for? ___________
- iii. sleep, how long do you sleep for? ___________
- iv. rest, without sleeping, for how long? ___________

D) other, please specify____

26. What makes you feel sleepy whilst driving? (more than 1 answer possible)

A) many hours working

B) many hours driving

C) monotonous work/roads

D) hot, stuffy cabs

E) lack of sleep

F) poor sleep quality

G) driving at certain times, please specify

H) noise, what noise?

I) other, please specify

J) don't feel sleepy whilst driving

27. Have you experienced any potentially dangerous driving incidents because you were sleepy? yes / no

If yes, what happened? (more than 1 answer possible)

A) nodded off/ fell asleep

B) nearly had an accident

C) drove off the road

D) collided with something

E) other, please specify________________________

____

28. Do you feel that you are falling asleep when driving? (please circle)

always / often / sometimes / seldom / never

29. Do you fall asleep unintentionally at work or at home? (please circle)

always / often / sometimes / seldom / never

30. In the last <u>6 months</u>, have you **nearly** had an accident due to being sleepy or tired?

A) never

B) once

C) more than once - how many times? _______________

31. Have you ever caused work accident because you fell asleep in your truck?

yes / no

If yes, how many accidents? ____

Briefly, what happened?

____

32. If you could do anything, what would you do to reduce shift work-related sleepiness?

____

____

____

____

33. THE MORNING SHIFT

a. How sleepy do you feel when you **START** a morning shift? (please mark one of the faces below)

b. How sleepy do you feel when you **FINISH** a morning shift? (please mark one of the faces below)

c. On average after a morning shift, how many hours do you sleep?

________ hours/day

d. Do you use anything to help you sleep better after the morning shift?

yes / no

If yes, what do you use, for example Milo, alcohol, sleeping pills?

____

e. When you sleep in the afternoon after a morning shift, is your sleep interrupted or disturbed?

always / often / sometimes / seldom / never

f. If your sleep is disturbed after a morning shift, what is the main source of the disturbance? (more than 1 answer possible)

A) noise or outside activity
B) heat or cold
C) sunlight/lights outside
D) uncomfortable bed/room
E) restlessness
F) snoring/ breathing difficulties
G) stress/ worrying

H) children / pets
I) other, please specify ____________________

Which is the biggest problem? A B C D E F G H I

34. THE AFTERNOON SHIFT

a. How sleepy do you feel when you **START** an afternoon shift? (please mark one of the faces below)

b. How sleepy do you feel when you **FINISH** an afternoon shift? (please mark one of the faces below)

c. On average after an afternoon shift**, how many hours do you sleep? hours/day**

d. Do you use anything to help you sleep better after an afternoon shift?

yes/no

If yes, what do you use, for example Milo, alcohol, sleeping pills?

____

e. When you sleep at night after an afternoon shift, is your sleep interrupted or disturbed?

always / often / sometimes / seldom / never

f. If your sleep is disturbed after an afternoon shift, what is the main source of the disturbance? (more than 1 answer possible)

A) noise or outside activity
B) heat or cold
C) sunlight/lights outside
D) uncomfortable bed/room

E) restlessness
F) snoring/ breathing difficulties
G) stress/ worrying
H) children / pets
I) other, please specify ______________________

Which is the biggest problem? A B C D E F G H I

35. THE NIGHT SHIFT

a. How sleepy do you feel when you **START** a night shift? (please mark one of the faces below)

b. How sleepy do you feel when you **FINISH** a night shift? (please mark one of the faces below)

c. On average after a night shift**, how many hours do you sleep?**
hours/day

d. Do you use anything o help you sleep better after a night shift?

yes / no

If yes, what do you use, for example Milo, alcohol, sleeping pills?

____

e. When you sleep during the day after a night shift, is your sleep interrupted or disturbed?

always / often / sometimes / seldom / never

f. If your sleep is disturbed during the day after a night shift, what is the main source of the disturbance? (more than 1 answer possible)

A) noise or outside activity
B) heat or cold
C) sunlight/lights outside
D) uncomfortable bed/room
E) restlessness
F) snoring/ breathing difficulties
G) stress/ worrying
H) children / pets
I) other, please specify ______________________

Which is the biggest problem? A B C D E F G H I

36. NUTRITION

a. What have you eaten in the past 24 hours? (please include quantities if possible)

____

____

____

____

____

b. When in the day do you have your main meal? ________________ am / pm (please circle)

c. Do you eat a meal before you start a work shift?

always / often / sometimes / seldom / never

d. Do you eat a meal after you finish a work shift or before you go to sleep?

always / often / sometimes / seldom / never

e. Do you space your meals more than five hours apart?

always / often / sometimes / seldom / never

37. Please complete the following sleepiness evaluation: The Epworth Sleepiness Scale

Please indicate how likely you are to doze off or fall asleep in the following situations, in contrast to just feeling tired? This refers to your usual way of life in recent times. Use the following scale to choose the most appropriate number in each situation:

0 = would never doze
1 = slight chance of dozing
2 = moderate chance of dozing
3 = high chance of dozing

What is the chance of you dozing off while:	score (0 / 1 / 2 / 3)
- sitting and reading?	______
- watching television?	______
- sitting inactive in a public place?	______
- being a passenger in a vehicle for an hour without a break?	______
- lying down to rest in the afternoon?	______
- sitting and talking to someone?	______
- sitting quietly after lunch with no alcohol?	______
- in a vehicle, while stopped for a few minutes in traffic	______

38. Please complete **The Horne-Östberg morningness / eveningness questionnaire** below.
Please place an X alongside one answer only, or place an X on the appropriate place on the scale.

a) Considering only your own "feeling best" rhythm, at what time would you get up if you were entirely free to plan your day?

am 5 6 7 8 9 10 11 12 noon

b) Considering only your own "feeling best" rhythm, at what time would you go to bed if you were entirely free to plan your evening?

pm 8 9 10 11 midnight 1 2 3am

c) If there is a specific time at which you have to get up in the morning, to what extent are you dependent on being awakened by an alarm clock or a wake up-call?

not at all dependent / slightly dependent / fairly dependent / very dependent

d) Assuming adequate and ideal conditions, how easy do you find getting up in the morning?

not at all easy / not very easy / fairly easy / very easy

e) How alert do you feel during the first half-hour after waking up in the morning?

not at all alert / slightly alert / fairly alert / very alert

f) How is your appetite during the first half-hour after waking up in the morning?

very poor / fairly poor / fairly good / very good

g) During the first half-hour after waking in the morning, how tired do you feel?

very tired / fairly tired / fairly refreshed / very refreshed

h) When you have no commitments the next day, at what time do you go to bed compared to your usual bedtime?

seldom or never later / less than 1 hour later / 1 – 2 hours later / more than 2 hours later

i) You have decided to engage in some physical exercise. A friend suggests that you do this 1 hour twice a week, and the best time for him is between 7 and 8 am. Bearing in mind nothing else but your "feeling best" rhythm, how do you think you would perform?

would be in good form / would be in reasonable form / would find it difficult / would find it very difficult

j) At what time in the evening do you feel tired and, as a result, in need of sleep?

pm 8 9 10 11 midnight 1 2 3 am

k) You wish to be at your peak performance for a 2 hour test that you know is going to be mentally exhausting. You are entirely free to plan your day. Considering only your own "feeling best" rhythm, which ONE of the four testing times would you choose?

8:00 – 10:00 am / 11:00 – 1:00 pm / 3:00 – 5:00 pm / 7:00 – 9:00 pm

l) If you went to bed at 11:00 pm, at what level of tiredness would you be?

not tired at all / a little tired / fairly tired / very tired

m) For some reason you have gone to bed several hours later than usual, but there is no need to get up at any particular time the next morning. Which ONE of the following events are you most likely to experience?

will wake up at usual time and will NOT fall asleep again ______________

will wake up at usual time and will doze thereafter ______________

will wake up at usual time but will fall asleep again ______________

will not wake up until later than usual ______________

n) One night you have to remain awake between 04:00 and 06:00 am in order to carry out a night watch. You have no commitments the next day. Which ONE of the alternatives will suit you best?

would NOT go to bed until watch was over ______________

would take a nap before and sleep after ______________

would take a good sleep before and nap after ______________

would take ALL sleep before watch ______________

o) You have to do 2 hours of hard physical work. You are entirely free to plan your day. Considering your own "feeling best" rhythm, which ONE of the following times would you choose?

08:00 – 10:00 am / 11:00 – 1:00 pm / 3:00 – 5:00 pm / 7:00 – 9:00 pm

p) You have decided to engage in hard physical exercise. A friend suggests that you do this for 1 hour twice a week, and the best time for him is between 10:00 and 11:00 pm. Bearing in mind nothing else but your own "feeling best" rhythm, how well do you think you would perform?

would be in good form / would be in reasonable form / would find it difficult / would find it very difficult

q) Suppose you can choose your own work hours. Assume that you worked a 5 hour day (including breaks), and that your job was interesting and paid by results. Which FIVE CONSECUTIVE HOURS would you select?

00 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 00

midnight am noon pm midnight

r) At what time of day do you think that you reach your "feeling best" peak?

00	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	00

midnight am noon pm midnight

s) One hears about "morning" and "evening" types of people. Which ONE of these types do you consider yourself to be?

definitely a 'morning type' ____________

rather more a 'morning' than an 'evening type' ____________

rather more an 'evening' than a 'morning' type ____________

definitely an 'evening' type ____________

Thank you for your time and comments

Appendix B

Supervisor's Guidelines on Fatigue Impairment

STEP 1. OBSERVATION

(What can be observed about this person's functioning/behaviour?)

	YES	NO
Is there a significant change in the person's behaviour ……………………	✍	✍

Physical Symptoms

	YES	NO
1. Eyes bloodshot ………………………………………………………………..	✍	✍
2. Slower movements………………………………………………………..	✍	✍
3. Poor co-ordination…………………………………………………………	✍	✍
4. Slower than normal response time e.g. response to radio contact……	✍	✍

Cognitive Functioning

	YES	NO
1. Distracted from task……………………………………………………….	✍	✍
2. Poor concentration/lapses in concentration……………………………….	✍	✍
3. Doesn't complete tasks ………………………………………………………	✍	✍
4. Short-term memory loss (forgets instructions)……………………………	✍	✍
5. Nodding-off momentarily……………………………………………………	✍	✍
6. Fixed gaze and/or reports blurred vision………………………………….	✍	✍

Emotion/Motivation

	YES	NO
1. Seems depressed………………………………………………………….	✍	✍
2. Irritable………………………………………………………………………	✍	✍
3. Doesn't care anymore…………………………………………………….	✍	✍
4. Easily frustrated with tasks………………………………………………..	✍	✍

If 3 or more indicators of fatigue are present, proceed to STEP 2.

STEP 2. RISK

	YES	NO
1. Has a fatigue-related incident occurred?…………………………………………	✍	✍
2. Has the person (self-report/by another person) been identified as at fatigue risk?	✍	✍
3. Is there a risk associated with the person's functioning/behaviour?……………. (i.e. risk to self, others or equipment)	✍	✍

3a. If Yes, What is the level of risk?…………………..✍High ✍Moderate ✍Low
(your best estimate)

If you form the view that the risk is unacceptable, proceed to Step 3.

STEP 3. CONVERSATION

Insight/Understanding

1. What is the person's explanation of what you have observed?………………….
………………………………………………………………………………..……….

Sleep

2. How many hours since they last slept?………………………………………..….______ ______ hours
3. How long did they sleep?…………………………………………………….…….____________ hours
4. Have they experienced a recent change in their sleeping habits?………………. ✍ ✍
5. Is there a reason/s for not enough sleep or poor sleep?………………………….
   ………………………………………………………………………………………….

Work

6. What tasks have they been working on this shift?…………………………….
   …………………………………………………………………………………..…..
7. Are those tasks "high-risk" for fatigue? I.e. repetitious or hot conditions …….. ✍ ✍
8. If Yes, How long have they been working on that task?……………………..__________ hours

Breaks

9. When did they last have a break in shift?……………………………………__________ hours
10. How long was that break?…………………………………………………..…..__________ hours

Fatigue Management

11. When did they last drink some water or eat something? (i.e. dehydrated or hungry?)
   ……………………………………………………………………………….…..______________hours
12. What do they usually do to prevent fatigue?……………………………….
   ……………………………………………………………………………………

STEP 4. SUPERVISORY ACTION

1. What is the level of risk associated with this person's continuing without intervention?………………………………………………………………. ✍ ✍
2. If that risk is unacceptable, what steps need be taken to minimise the immediate risk?
   a. Task rotation option…………………………………………….. ✍ ✍
   b. Short break option……………………………………………….. ✍ ✍
   c. Go home option……………………………………………….…. ✍ ✍
3. Has this person been associated with previous fatigue issues?…………... ✍ ✍
4. Follow-up procedures:
   a. First occasion – deal with it informally, but record incident…… ✍ ✍
   b. Incident report completed………………………………………. ✍ ✍
   c. Training in fatigue management recommended…………………. ✍ ✍
   d. Referral to EAP………………………………………………. ✍ ✍

Reference: Shaw, A., 2003 Guideline of fatigue management. Published by Shaw Idea Pty. Ltd. (Guideline incorporate material based on Queensland Guideline Note for Management of Safety and Health Risks associated with Hours of Work Arrangements at Mining Operations