



MANDELA MINING PRECINCT
MINDS FOR MINES

Programme:
Longevity of Current Mines (LoCM)

Work Package 6:
Shift Cycles and Productivity

Milestone 8:
Final Report

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Date: November 2019

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List of acronyms

AWOP	:	Absent Without Permission
BCEA	:	Basic Conditions of Employment Act
CL	:	Chairlift
CONOPS	:	Continuous Operations
COP	:	Code of Practice
DMR	:	Department of Mineral Resources
FIFO	:	Fly In Fly Out
FULCO	:	Full Calendar Operations
KPI	:	Key Performance Indicator
LHD	:	Load Haul Dump Machine
LoCM	:	Longevity of Current Mines
MHSA	:	Mine Health and Safety Act
NUM	:	National Union of Mineworkers
OHS	:	Occupational Health and Safety
OHSA	:	Occupational Health and Safety Act
PDCA	:	Plan-Do-Check-Act
PGM	:	Platinum Group Metals
PTV	:	Pipes, Tracks and Ventilation
SAMERDI	:	South African Mining Extraction Research, Development and Innovation
SAMI	:	South African Mining Industry
SATCAP	:	Successful Application of Technology Centred Around People
UASA	:	United Association of South Africa
UV	:	Utility vehicle

Executive summary

Introduction

Most narrow reef gold and platinum group metals (PGM) mines are getting deeper, and increased travelling times reduce the time available to complete work requirements. Other ancillary activities taking place in the mining cycle further reduce time spent at the work face, and might not support the attainment of a daily conformant blast. Increased shift lengths and adoption of close to continuous operations (CONOPs) could help to address these challenges. Meanwhile, the effects of worker travelling times from home to the stope face and the impacts working conditions on worker fatigue are not well understood. This project aimed to investigate the impact on worker commuting times on fatigue, to document activities that affect available face time, and to draft a framework for optimising shift cycles, while considering productivity and occupational health and safety (OHS). The framework was informed by two literature reviews, and two case studies conducted in the in the South African mining industry (SAMI).

Fatigue and other impacts of shift cycles on people

The first literature review provides an overview of fatigue of mine workers in the context of shift work, and also provides a background of the related effects of worker commuting times. Shift work is required in many industries and allows for longer hours of operation. However, shift work is also associated with fatigue, occupational accidents, impaired physical and psychosocial health, sick leave, absenteeism, and negative impacts on social and domestic activities. Fatigue, in turn, contributes to reduced performance and productivity, and increased risk of errors, incidents, accidents, and injuries in the mining industry. Numerous work scheduling factors are associated with the risk of fatigue and accidents, including the time of day, shift length, the direction and speed at which shifts are rotated, and breaks during work and between shifts. Other factors that can contribute to fatigue include the job demands, work environment, medical conditions, lifestyle and activities performed outside of work, nutrition, demographics, socioeconomic status, living conditions, and commuting times. Increased commuting times are associated with reduced sleep, increased sleepiness, and impaired health, mental well-being, and productivity. All of the factors listed above should be considered when scheduling shift cycles in the mining industry.

Optimising productivity with a focus on shift cycles

The second literature review focusses on shift cycles from a productivity perspective. Globally, in response to economic, technological, and social pressures, organisations have adopted 24-hour operations. This requires organisations to adapt to different shift cycles. Shift work is traditionally defined as work conducted outside of 06:00 to 18:00, five-day work weeks, and incorporates regular rotating shifts, irregular on call work, a combination of both, or permanent night shift work. There are challenges within shift cycles that have contributed to workers being unable to complete their mining tasks or activities, which results in production targets not being achieved. These challenges are discussed in this report, and they have prompted the need to consider different shift cycles, with the objective of optimising productivity. The premise is that redesigning the shift schedules to enable optimum production hours per day and production

days per month will potentially result in improved productivity. However, this approach has to take a holistic consideration of factors such as legislation in terms of working hours, the nature of the mine, the mining method used, workplace culture, impact of the shift schedule on OHS and other social factors. The advantages and disadvantages of changes of shift cycles from 8 hours to 12 hours are highlighted by the literature. Advantages include, amongst other things, improved communication at shift changeovers and increased productivity. For the worker, the benefits include reduced total travelling time, and longer blocks of non-work time, which means more social and family time. Disadvantages identified include fatigue, increased sleepiness and increased rate of accidents and injuries. In the mining industry, shift cycles are altered to manage fatigue while working towards achieving production targets and to maintain the survival of the mines. Additionally, various other factors are highlighted to be affected by or have an impact on shift cycle changes, and need to be carefully taken into consideration when designing shift cycles. Such factors include the involvement of the employees in the design of the new shift cycles, the link between changing shift cycles and absenteeism, supervision, education and training, and social support and culture.

Data collection and analysis

An assessment of shift cycles and productivity was conducted at a mechanised gold and a mechanised PGM mine in South Africa. Continuous operations (CONOPs) were successfully implemented at these operations. The main benefit of the CONOPs system was improved productivity, with face times of between six and ten hours reported during shifts taking place twice per day. Additionally, maintenance was improved, as service shifts were incorporated into the rosters. The use of contingency measures such as availability of spare panels, and extra roving crews also aided continued production. However, challenges associated with the longer shifts that were implemented included increased fatigue and absenteeism. Commuting times, rest breaks during work, and the workplace environmental conditions (e.g. heat) were also considered in terms of fatigue associated with shift work. An analysis of the fatigue and accident risks associated with selected CONOPs rosters was conducted, and the risks were higher with longer shifts, during night shifts, and when numerous consecutive shifts were worked. The assessment of shift cycles and fatigue should consider a number of factors, and be developed to suit the unique needs of each operation. Consultation between stakeholders, including mining companies and worker representation, is important for the successful implementation of changes to shift cycles.

Draft framework

A framework was drafted to assist operations to determine the most suitable shift systems that can be implemented to enhance productivity and efficiency, while supporting the health, safety and quality of life of the workforce. Optimising the shift rosters could help to improve productivity and OHS in the SAMI. Various considerations should be made when considering changes to shift cycles. These considerations include those relating to operational requirements, OHS requirements, and employee needs.

Workshop

A workshop was held to present and discuss the findings from this project, and to gain technical input into the draft framework. The participants included stakeholders from mining companies, research partners, steering committee members and co-directors of the Mandela Mining Precinct. Feedback received from the stakeholders was used to update and refine the draft framework, and to identify future research topics.

Conclusion

The draft framework developed in this project serves as a basis for further industry engagements and recommended research for the optimisation of shift cycles in the SAMI. Further stakeholder engagements, including those with union representatives, will be required prior to the finalisation of the framework or guidelines for shift cycles. This work should be scoped into future project phases, as it does not fall within the scope of this project.

1. Introduction

1.1. Background

Most narrow reef gold and platinum mines are getting deeper and working faces have progressed further from the shafts; this results in longer travelling times and reduced face time. Along with increased travelling times, additional work activities are required, such as safety meetings, 'making safe' procedures, and installing safety nets or roof bolts. As a result of the long travelling times and activities taking place during the mining cycle, current shift times might not support a daily conformant blast. Additionally, the effects of travelling from home to the stope face are not well understood, particularly in terms of fatigue. The time taken from when workers leave home in the morning until the time they return home after work could be in excess of 14 hours. Further aspects that are affected by shift schedules, including heat stress, need to be considered. A better understanding of commuting times and ancillary activities that affect face time will assist to develop a framework for optimising shift cycles in the mining industry.

1.2. Aims and objectives

The aims of the project are:

- To investigate the impact of home to work travelling on workers' fatigue; and
- To identify feasible alternative shift cycles applicable to narrow reef underground mines in South Africa.

The related project deliverables include:

- Documentation of the impact of commuting on workers' vulnerability to fatigue;
- Documentation on potential challenges in different ancillary activities on available face time; and
- A framework for optimising shift cycles, to maximise asset utilisation and OHS in the South African mining industry (SAMI).

The project milestones and related activities are shown in Table 1.

Table 1: Project milestones and activities

No.	Milestone	Activities
1.	Project initiation	<ul style="list-style-type: none"> • Project planning and administration • Hold discussions and establish collaborations with relevant individuals and projects
2.	Literature review on fatigue, and other impacts of shift cycles on people	<ul style="list-style-type: none"> • Compile and read relevant literature • Draft literature review on factors such as transport issues, fatigue, psychosocial factors, and absenteeism, in relation to shift cycles • List fatigue-related factors to consider relating to shift cycles in the mining industry • Review and submit
3.	Literature review on optimising productivity, with a focus on shift cycles	<ul style="list-style-type: none"> • Compile and read relevant literature • Draft literature review on optimising productivity, with a focus on shift cycles • List different shift cycles in use globally and relevant work-related factors to consider, such as ancillary activities, available face time, supervision, skills, logistics, and maintenance • Review and submit
4.	Data collection plan	<ul style="list-style-type: none"> • Develop data collection tools and study protocol • Workshop to discuss study and receive input into the data collection tools and protocol • Review data collection tools and protocol • Compile and submit documentation to research ethics committee for review and approval
5.	Data collection and analysis	<ul style="list-style-type: none"> • Identify data collection sites and request participation in study • Conduct data collection, which may involve a desktop survey, interviews and focus group discussions, questionnaires, and time-motion studies • Data capturing and analysis • Draft and review report on findings
6.	Draft framework	<ul style="list-style-type: none"> • Collate findings from research conducted • Draft a framework for the optimisation of shift cycles* <p>*The framework will include a value proposition, change management and implementation strategy, which will be developed in collaboration with the SATCAP research programme</p>
7.	Workshop	<ul style="list-style-type: none"> • Hold workshop with stakeholders for input into the draft framework
8.	Final report	<ul style="list-style-type: none"> • Incorporate inputs from workshop • Finalise and submit report

1.3. Methods

1.3.1. Initial engagements

Initial engagements were held with industry experts to gain an understanding of the numerous factors to consider relating to shift cycles in the mining industry, and of previous work that was conducted in this domain (e.g. the Sindisa project). Related documentation was also obtained and included in the literature reviews. The initial engagements further provided a basis for collaboration with the related Successful Application of Technology Centred Around People (SATCAP) project, which focusses on “change processes and stakeholder engagement for shift cycles appropriate to modernisation”.

1.3.2. Literature reviews

The literature reviews provided further background information for the research, and an understanding of local and international research relating to shift cycles in the mining industry. The first literature review focussed on how shift cycles are associated with fatigue, along with numerous associated factors including health, safety, and absenteeism. The effects of worker living conditions and commuting times to and from work were also considered. The second literature review focussed on different shift cycles in use locally and globally, and how shift cycles and ancillary activities in mines are associated with productivity. Social and occupational health and safety (OHS) risk factors in the design of shift cycles were also incorporated.

1.3.3. Data collection

i. Data collection workshops

A number of meetings were held to discuss the data collection plan for the study. Various data collection options were considered including workshops, focus groups, interviews, and questionnaires, while the potential study participants included stakeholders such as industry experts, mine managers, union representatives, and mine workers. It was decided that data collection for this study would involve case studies at mine sites in South Africa. A workshop would follow data collection and analysis to discuss the findings with stakeholders and to gain feedback and further input. The planned methodology for the case studies is described in this section.

ii. Study sample

Case studies were planned to take place at two gold mines and two platinum mines in South Africa. However, data collection only took place at two mines (one gold and one platinum mine), as a result in difficulties in gaining access to further identified sites during the study period. Convenience sampling was used to identify potential mine sites. The mines were identified based on input and understanding of experts in the field.

Data were collected from participants at each mine that had an in-depth knowledge of the operation and access to required data. These participants included Human Resources (HR), Mine Planning, and Production personnel.

iii. Study design and measures

This was a mixed methods study, as both qualitative and quantitative data were gathered. The qualitative were gathered in interviews and focus group discussions held with the participants. Related themes included shift cycles, ancillary activities, face time, travelling times, work conditions, resources, and fatigue. Quantitative data were gathered in the form of data provided by the mines. This data included the shift rosters and shaft schedules, productivity, health and safety data, and shift activity durations, where available. Clock-in and clock-out times for workers in teams with low, medium, and high productivity were requested, for an analysis of planned versus actual bank-to-bank times, and associated productivity outcomes. The data collection tool for the study is attached in Annexure A.

iv. Study protocol

The potential mines sites and contacts for each mine were identified. A request for participation was then sent to the contact people at these mines. Upon feedback from the contact people, data collection expectations and arrangements were discussed and, where agreed upon, required permissions were received. Visits to the mines were scheduled and necessary processes followed. At the mines, meetings were held with the identified participants to gather the necessary data and information.

v. Data analysis

The data gathered were captured into an electronic format. Basic statistical analyses, including frequencies, percentages, means, and standard deviations, were conducted on the quantitative data. Complete shift cycle data were modelled using software to estimate fatigue and accident risk. Thematic analysis was used to analyse the qualitative data, and themes from the data were coded and summarised.

1.3.4. Ethics

Ethics approval for the project has been granted by the CSIR Research Ethics Committee (reference number: 239/2017). The ethics clearance letter is attached in Annexure B. According to ethics requirements, all data will remain confidential, including the names of the participating mines and individuals. Voluntary informed consent was gained from each participant. Feedback will be provided to the participants following study completion.

1.4. Draft framework

A framework was drafted based on the literature reviews and the data gathered in this project. The draft framework was shared with various stakeholders, including mining companies and industry experts for review.

1.5. Workshop

A workshop was held with stakeholders to discuss the study findings, and to gather technical input into the draft framework. Attendees included representatives from mining companies, Mandela Mining Precinct co-directors, technical steering committee members, research partners and industry experts. Further workshops with broader stakeholders, including unions, are planned prior to finalisation of the framework or guidelines for the industry.

1.6. Conclusion

Data collected in this study informed a framework for optimising shift cycles in the SAMI. This framework is intended to assist stakeholders to determine the most appropriate shift cycles for each mining operation, while taking productivity and OHS risk factors into account. Related aspects to consider include ancillary activities, maintenance, logistics, resources and support, health and safety, absenteeism, employee preferences, and commuting times. Direction on change management and implementation processes is also provided.

2. Fatigue and other impacts of shift cycles on people

2.1. Introduction

Work conducted in the first year of the Longevity of Current Mines (LoCM) programme included a detailed gap analysis to identify recommendations for the improvement of mining cycle elements for conventional narrow reef gold and platinum operations to enable one conformant blast per day. For the purpose of the study, a conformant blast was defined as a blast which conformed to the minimum standards of a particular mine, looking at parameters such as safety, compliance to standards, face advances, fragmentation, cleaning, and rock removal. Most conventional narrow reef gold and platinum mines are getting deeper and the working faces have progressed further from the shafts. Consequently, the employees spend a significant portion of their shift time travelling to and from underground working places, and the available face time is therefore reduced; this places the conformant blast at risk. The available face time is also impacted on by mine operational requirements such as safety meetings, making safe and risk management issues at the start of and throughout the shift. In the project report, Rupprecht (2018) noted that the mandatory shift length of 8h20min (500 minutes) may not support a daily conformant blast, as a result of long travelling times underground, and activities taking place during the mining cycle. Moreover, it was identified that the “Effects of travelling from home to stope face is not understood, especially regarding its effects on fatigue” (and absenteeism) and “Ineffective integration of vertical and horizontal transport causes transportation bottlenecks” (Gumbie, 2018, p13). In order to close these gaps, Gumbie (2018) recommended the following further studies:

- To investigate the impact of different modes of transport on personnel travelling times from their residence to the shaft, and its impact on productivity;
- To investigate optimal shift systems and work rotation; and
- To investigate human element inputs into mining, including absenteeism and a lack of motivation by the workforce.

This review of literature focuses on aspects relating to worker fatigue, including the effects of travelling between home and work. Various impacts of shift cycles on workers are also detailed in this review, which include aspects such as health, safety, and social factors. Related matters that should be considered include, for example, stope heat and humidity in relation of the amount of time spent in the stope, and time to attend to personal matters, including shopping and preparing food, outside of shift times. As such, the review assists with the fulfilment of the recommendation made in the first year of the research: “to undertake a study to understand the total duration a typical mine worker encounters during a normal working shift, from the point of leaving home, to returning to his place of residency. This study should further strive to understand the social and economic(al) impacts of this work cycle i.e. how [the] work [cycle] impacts on the worker in terms of health, fatigue, absenteeism, family life, and economic aspects such as ability to pay bills and other financial commitments” (Rupprecht, 2018, p11).

2.2. Shift work

Shift work is a common practice in the South African mining industry in order for mines to meet production and occupational health and safety (OHS) requirements. Shift work can be defined

as “an organisation of work where workers succeed each other at the same workplace while performing similar operations at different times of the day thus allowing longer hours of operation than feasible for a single worker” (South Africa, 2014, p5). Continuous shift work refers to when “the employer operates 24 hours a day, seven days a week, all year round”, while semi-continuous shifts operate “24 hours a day without a daily break, but with a break at the weekend”; discontinuous shift work refers to when “the employer operates less than 24 hours per day with at least one daily break” (e.g. ‘two-shift’ system) (South Africa, 1998, p5). For the purposes of this research, the term continuous operations (CONOPS) is used interchangeably with full calendar operations (FULCO), and refers to operations that operate on seven days per week throughout the year. Many industries, including medical, power, mining and smelting industries, require 24 hour operations (Baulk *et al.*, 2009). Rostering systems typically involve 3 x 8 hour shifts or 2 x 12 hour shifts each day. Examples of 12 hour shift systems are 2D-2N-4O, 4D-4O-4N-4O, and 7D-7O-7N-7O (where D refers to ‘day’, N ‘night’ and O ‘off’) (Baulk *et al.*, 2009). These examples are illustrated in Figure 1.

Example 1	
	Day
	1 2 3 4 5 6 7 8
Team A	D D N N O O O O
Team B	O O D D N N O O
Team C	O O O O D D N N
Team D	N N O O O O D D

Example 2	
	Day
	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Team A	D D D D O O O O N N N N O O O O
Team B	O O O O D D D D O O O O N N N N
Team C	N N N N O O O O D D D D O O O O
Team D	O O O O N N N N O O O O D D D D

Example 3	
	Day
	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
Team A	D D D D D D D O O O O O O O N N N N N N N O O O O O O O
Team B	O O O O O O O D D D D D D D O O O O O O O N N N N N N N
Team C	N N N N N N N O O O O O O O D D D D D D D O O O O O O O
Team D	O O O O O O O N N N N N N N O O O O O O O D D D D D D D

Figure 1: Examples of 12 hour shift systems (D=day; N=night; O=off)

The literature reviewed indicated a number of negative effects of shift work. Shift work has negative effects on social and domestic activities, and long-term effects on physical and psychosocial health (Baulk *et al.*, 2009). Shift work is associated with disturbed sleep, fatigue, occupational accidents, and chronic conditions including cardiovascular disease and diabetes (Härmä *et al.*, 2018). Disruptions in the sleep-wake cycle result in reduced alertness and poorer performance, which affect occupational health and safety (Baulk *et al.*, 2009). Additionally, ongoing shift work can have cumulative effects, such as chronic sleep loss and long-term impacts on health (Baulk *et al.*, 2009).

A number of factors are associated with the risk of fatigue and accidents during shift work, and are discussed further below. These factors include:

- Time of day;
- Direction and speed of shift rotation;
- Consecutive shifts;
- Consecutive hours on duty;

- Length of shift cycle;
- Breaks between work periods;
- Rest breaks during work; and
- Job demands.

The Department of Mineral Resources (DMR)'s Guideline for a Mandatory Code of Practice for Risk-Based Fatigue Management at Mines (South Africa, 2014, p21) lists aspects relating to shift schedules or work time arrangements that could reduce a person's ability to adjust to shift work, including:

- "A shift roster with an irregular or unpredictable pattern;
- More than four consecutive 12-hour night shifts;
- More than five consecutive 8-hour night shifts;
- Work schedules/rosters that do not allow for continuous sleep of seven to eight hours in each 24-hour period;
- Excessive regular overtime and on-call work;
- Early morning shift start times (before 06:00);
- Backward rotating rosters (day to night to afternoon);
- Shifts lacking appropriate shift breaks;
- Less than 36 hours off after a period of night shift work;
- 12-hour shifts that involve critical monitoring tasks, heavy physical work, potential exposure to harmful agents/substances."

2.2.1. Shift timing

Shift work is characterised by work at unusual times, such as during evenings and weekends. The literature reviewed revealed that work at unusual times might lead to desynchronization with social participation and biological rhythms (Greubel *et al.*, 2016). Greubel *et al.* (2016) found that work at unusual times has been associated with increased risk of poor work-life balance, work-related health complaints, and occupational incidents. These increased health and safety risks could lead to economic losses resulting from increased sick leave and staff turnover rates (Greubel *et al.*, 2016).

Work schedules that compel workers to be awake at night, or work for extended periods, disrupt circadian rhythms (Theron, 2014). Disruption of the circadian rhythm is a major factor that contributes to fatigue or sleepiness at work (Schutte, 2010). The circadian rhythm can be defined as "the internal cycle of roughly 24 hours that regulates physiological and behavioural activities of all living organisms – also referred to as the 'body clock'" (South Africa, 2014, p5). The human circadian rhythm is associated with increased alertness and performance during daylight hours, and the physiological drive to sleep at night (Schutte, 2010). Altering the normal sleep-wake cycle, such as by non-traditional working hours, creates a misalignment between the internal body clock, activities and sleep schedules (Schutte, 2010).

Spencer *et al.* (2006) reported that both fatigue and incident risk are highest during night shifts, while highest incident risk is around midnight, and peak fatigue occurs in the early morning, approximately five hours later. Figure 2, for example, illustrates fluctuations in both sleepiness and performance over the course of 26 hours, with increased fatigue and response slowing

evident in early morning hours. Figure 3 illustrates differences in relative risk across three shift types. Early morning shifts and night shifts are associated with shorter sleep durations, along with increased levels of sleepiness and fatigue (Härmä *et al.*, 2018; Spencer *et al.*, 2006). Shift schedules that are misaligned to circadian rhythms, and high workloads contribute to high rates of sleep deprivation (Kalmbach *et al.*, 2018). Shift workers tend to receive less sleep than those that work the same length of time during ordinary hours, and sleep quality during the day is usually poor (Theron, 2014). Baulk *et al.* (2009) suggested that taking a nap, or extra 'preparatory' sleep, prior to the first night shift could help to reduce extended wakefulness.

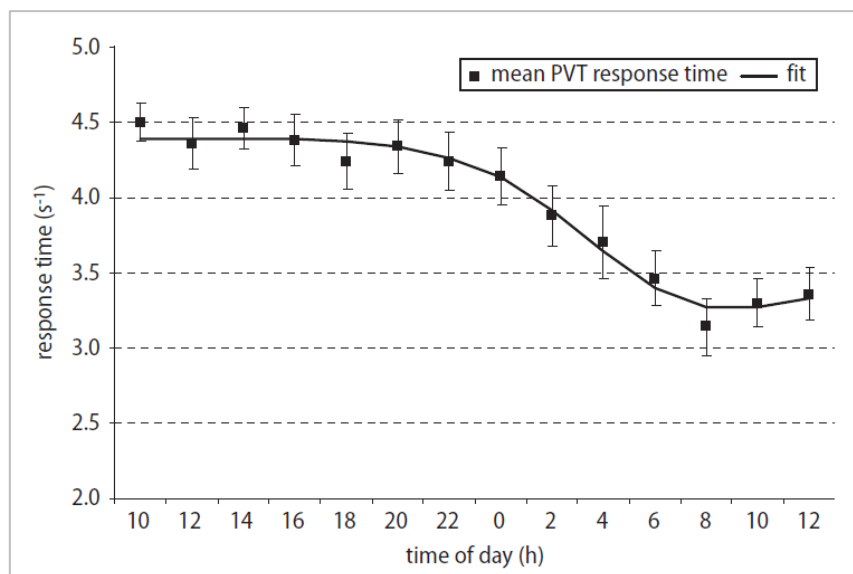


Figure 2: Fit to psychomotor vigilance task (PVT) performance data based on transformed Karolinska Sleepiness Scores; higher values indicate quicker responses (taken from Folkard *et al.*, 2007, p180)

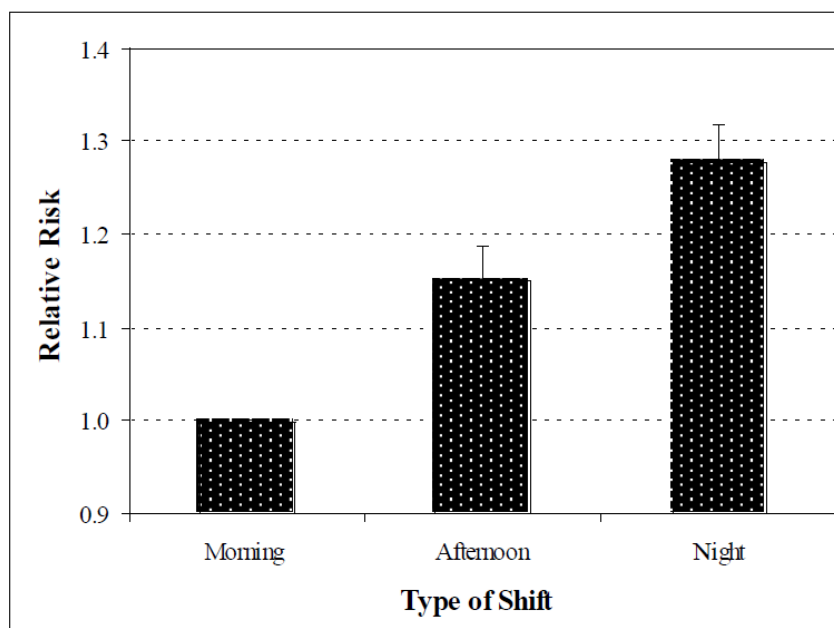


Figure 3: The relative risk across three shifts; error bars are 95% confidence intervals (taken from Spencer *et al.*, 2006, p28)

2.2.2. Shift rotation

Rotating shifts refer to when workers alternate between different shifts. The rotation can be forward (i.e. clockwise e.g. morning to afternoon to night) or backward (anti-clockwise) (South Africa, 1998). The use of forward-rotating shifts is generally supported, as this system allows sufficient time between shifts to allow for recovery, and avoid 'quick returns' (11 hours or less between shifts) (Härmä *et al.*, 2018). Forward rotating shift schedules have been associated with better sleep quality and less work-family conflict (Spencer *et al.*, 2006). Although there is conflicting evidence about the preferable speed of shift rotation, the use of quickly rotating shift systems, in which two or fewer consecutive night shifts are worked, is generally considered preferable to improve sleep and neurobehavioral performance (Härmä *et al.*, 2018). Individuals working rotating shift patterns might have more difficulty falling asleep and have poorer performance than those working fixed shifts (Spencer *et al.*, 2006). In terms of permanent night shift work, it was noted that the majority of shift workers showed no adaptation, while around 30% of workers showed some level of adjustment to working night shifts (Spencer *et al.*, 2006).

In a study by Kalmbach *et al.* (2018), it was found that changes in shifts were associated with sleep deprivation, where greater sleep deprivation was evident for advanced (earlier) than for delayed (later) sleep as a result of shift changes. Shorter sleep durations were associated with poorer mood (Kalmbach *et al.*, 2018). The participants also reported poorer moods following sleep timing that was shifted by three or more hours (Kalmbach *et al.*, 2018).

2.2.3. Shift and cycle lengths

Extended duty shifts and work hours affect fatigue and error rates (Bates, 2009). Increased shift lengths are associated with increased risk of fatigue and falling asleep during the shift (Spencer *et al.*, 2006). Estimated risk of different shift lengths is illustrated in Figure 4. Extended work hours reduce the amount of time available for sleep and social activities (Theron, 2014). Additionally, excessive wakefulness causes reduced alertness and performance; lapses in performance are expected following 16 hours of continual wakefulness (Spencer *et al.*, 2006).

Incident risk increases with time on task and number of consecutive days (Spencer *et al.*, 2006). An increase in performance errors and reduced alertness has been reported over consecutive night shifts (Spencer *et al.*, 2006). Figure 5 and Figure 6 illustrate relative risk over consecutive night and day shifts, respectively. Sufficient recovery time between shifts is important, and it is reported that limiting sleep to six hours or less on consecutive nights results in cumulative impairments in performance (Spencer *et al.*, 2006). However, a slow accumulation of sleep loss could lead to fewer performance decrements than a rapid accumulation of sleep debt (Spencer *et al.*, 2006). Theron (2014) reported increased occupational health and safety risks for people working more than 60 hours a week, or 12 hours or more per day. Incident or injury rates were doubled following 12 hours of work compared to an 8 hour shift; furthermore, these incident/injury rates increased by 17% after a fourth day shift, and by 30% on the fourth night shift, compared to the first (Theron, 2014). Other factors that affect the level of risk include rest breaks, and prophylactic naps (i.e. short sleeps to prevent the onset of fatigue) (Spencer *et al.*, 2006). The duration of continuous duty without a break has been seen to contribute to fatigue, sleepiness, and the risk of incidents, as illustrated in Figure 7 (Spencer *et al.*, 2006).

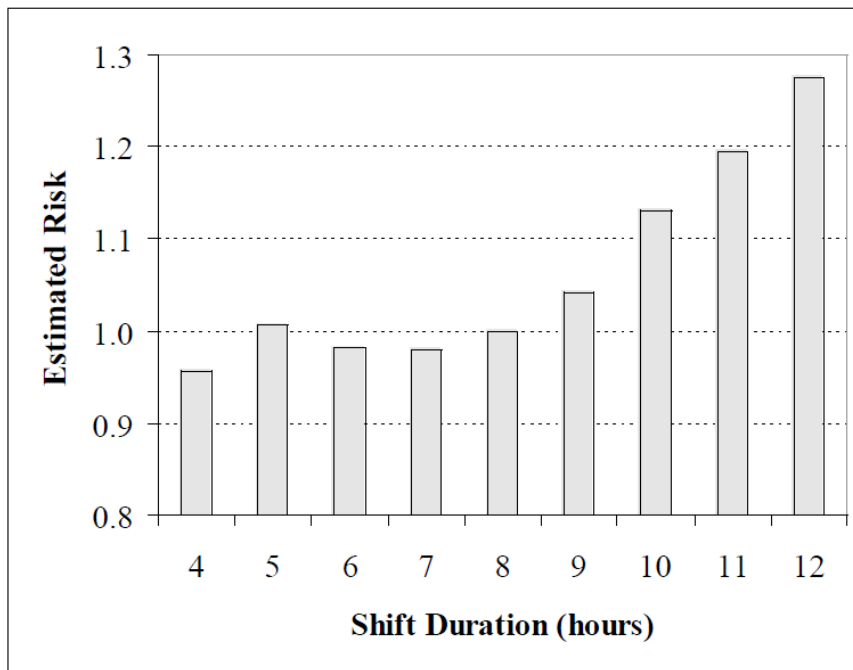


Figure 4: The estimated relative risk of shifts of different lengths (taken from Spencer *et al.*, 2006, p37)

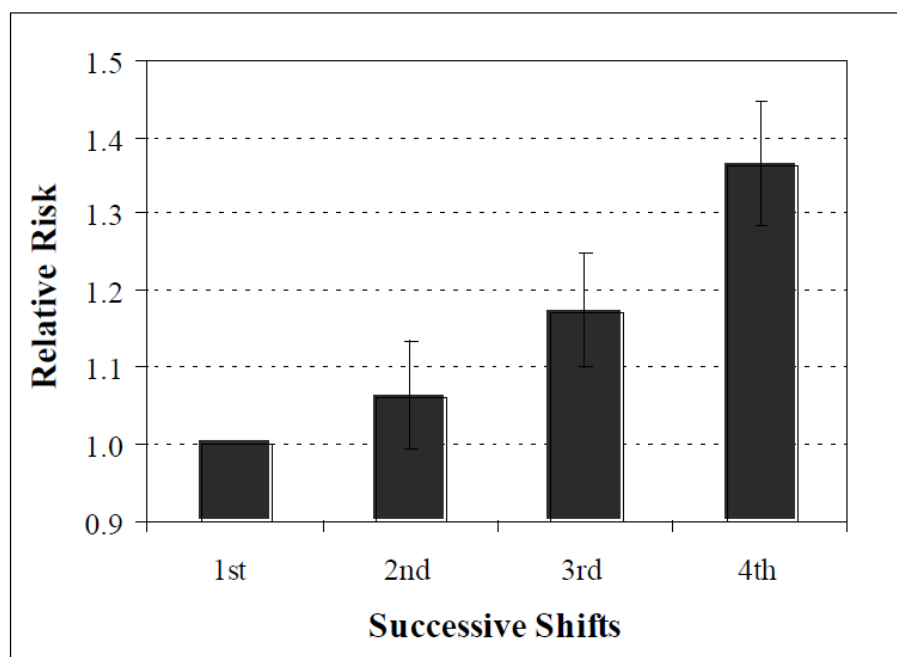


Figure 5: The relative risk over four successive night shifts; error bars are 95% confidence intervals (taken from Spencer *et al.*, 2006, p33)

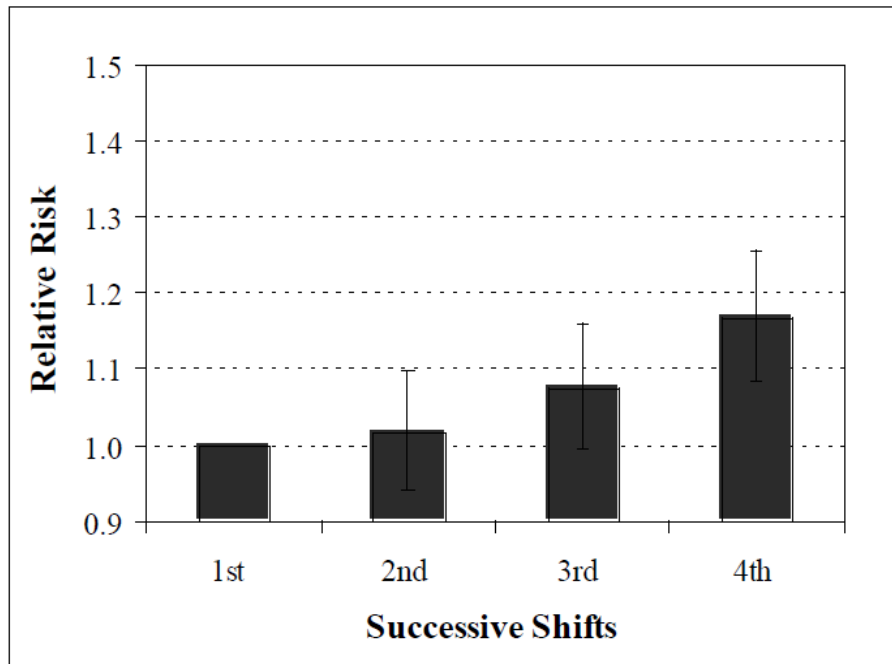


Figure 6: The relative risk over four successive morning/day shifts; error bars are 95% confidence intervals (taken from Spencer *et al.*, 2006, p34)

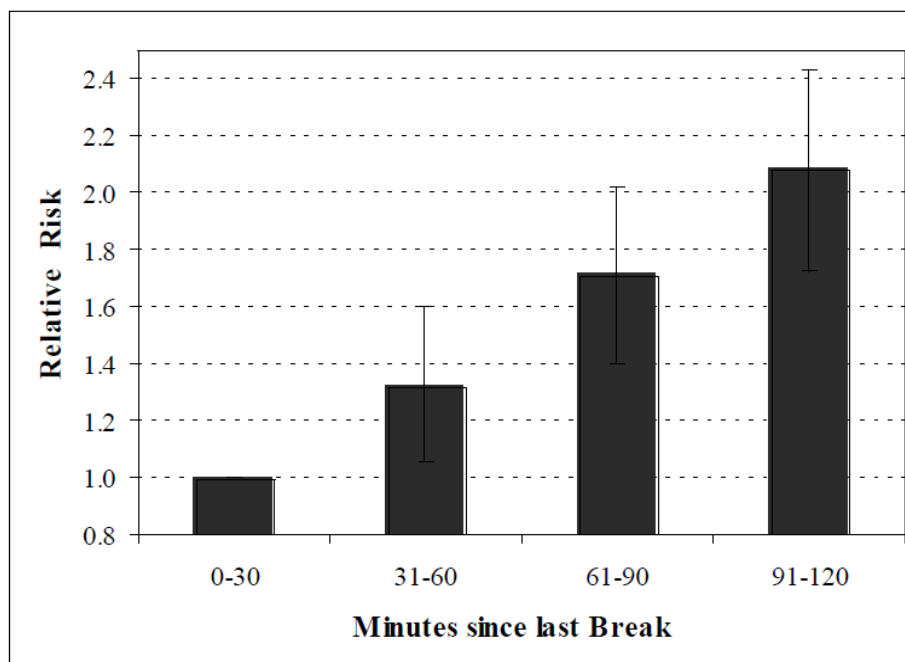


Figure 7: The trend in relative risk between 2-hourly breaks; error bars are 95% confidence intervals (taken from Spencer *et al.*, 2006, p39)

The use of 12-hour shifts results in compressed working weeks, which could be favourable as this allows for longer periods of time off for social and domestic interaction and leisure time, and results in a reduction in total commuting time (Baulk *et al.*, 2009). However, the disadvantages of 12-hour shift systems include increased risk of fatigue and accidents, and reduced performance (Baulk *et al.*, 2009). These risks apply particularly for night shifts, early morning shifts, towards the end of the shift, when the job is monotonous or involves continuous

physical work, and during the first shift after rest days (Baulk *et al.*, 2009). Baulk *et al.* (2009) also noted that the amount of time off during 12-hour shift systems could allow time for workers to undertake a second job. The regulation of overtime is also a key issue with 12-hour shift systems in terms of the potential for increased fatigue and reduced alertness (Baulk *et al.*, 2009). Baulk *et al.* further recommend the regulation of travelling or commuting, as this potentially impacts on wakefulness and increased accident risk.

Rupprecht (2018) reported on findings of Phase 1 of the LoCM thematic area, which indicated that some workers were working longer than 45 hours per week, which is in excess of the hours set out in the Basic Conditions of Employment Act (BCEA) of 1997. The reasons for working extra hours could be because workers wanted to maximise earnings; however, these long hours were also indicated to interfere with personal lives and result in issues such as lost family time and fatigue (Rupprecht, 2018).

2.2.4. Legislation about shift work

Shift work and working hours in South Africa are subject to legislation and regulations, such as the BCEA (Act No. 75 of 1997), the Occupational Health and Safety Act (OHSA, Act No. 85 of 1993), and the Mine Health and Safety Act (MHSA, Act No. 29 of 1996) (South Africa, 1993, 1996 and 1997).

The BCEA sets out regulations for the working time of employees (South Africa, 1997). These regulations include sections relating to ordinary hours of work, overtime, compressed working weeks, averaging the hours of work, meal intervals, daily and weekly rest periods, pay for work on Sundays, night work, and public holidays (Chapter 2, Sections 6-18). In terms of Section 9(1), subject to further provisions, “an employer may not require or permit an employee to work more than:

- a) 45 hours in any week; and
- b) Nine hours in any day if the employee works for five days or fewer in a week; or
- c) Eight hours in any day if the employee works on more than five days a week.”

However, Section 11(1,2) of the BCEA stipulates that, upon agreement, employees may work up to 12 hours a day without receiving overtime pay, but the agreement “may not require or permit an employee to work:

- a) More than 45 ordinary hours of work in any week;
- b) More than ten hours’ overtime in any week; or
- c) On more than five days in any week.”

Furthermore, Section 12 indicates that the ordinary hours of work and overtime may be averaged over a period of up to four months, in terms of a collective agreement, as long as the work does not exceed an average of 45 hours of ordinary hours per week, and an average of five overtime hours per week over the agreed period. Section 15 indicates that daily rest periods of at least 12 consecutive hours between ending and recommencing work are required. Weekly rest periods of 36 hours or more are required, which must include a Sunday, unless otherwise agreed; an agreement may provide for a rest period of at least 60 hours every two weeks, or reduction of the weekly rest period by eight hours in any week, if the rest period in the following week is equivalently extended (Section 15). In terms of meal intervals, “an employer

must give an employee who works continuously for more than five hours a meal interval of at least one continuous hour”; this meal interval may be reduced to 30 minutes subject to an agreement in writing (Section 14).

Overtime of employees needs to be in accordance with an agreement between the employer and employee, and not more than three hours per day, or ten hours per week, subject to further provisions (Section 10(1)). Provisions for compensation for overtime work, work on Sundays, public holidays, and night shifts are further included in the BCEA. Agreements are required for work performed on public holidays.

Night shift work refers to work performed after 18:00 and before 06:00 the following day (Section 17). Night shift work is subject to the availability of transportation between the employee’s place of residence and the workplace at the start and end of the shift. Employers are also to inform employees of health and safety hazards associated with the work, and the employee’s right to undergo medical examinations concerning those hazards, which are for the employer’s account. The MHSA and OHSA similarly stipulate that employers must ensure that employees who perform regular night work must be informed of the hazards associated with the work (South Africa, 1998 and 2014).

The BCEA further refers to the Code of Good Practice (COP) on the Arrangement of Working Time. The COP further relates to the MHSA and OHSA, as employers may be required to take working-time schedules into account to ensure that the working environment is safe and will not risk the health and safety of employees (South Africa, 1993, 1996 and 1998). The MHSA and OHSA indicate requirements for employers to conduct a risk assessment, implement measures to eliminate or control identified hazards, and train and inform employees about the risks and controls (South Africa, 2014). The MHSA requires that employers implement a Code of Practice (COP) on any matter that can affect the health and safety of employees or other people that may be directly affected by mine activities, if required by the Chief Inspector of Mines (South Africa, 1996 and 2014). This requirement is also reflected in the Guideline for a Mandatory Code of Practice for Risk-Based Fatigue Management at Mines, which aims to assist the employer of every mine to prepare at risk-based COP on fatigue management (South Africa, 2014).

The COP on the Arrangement of Working Time relates to shift work, night work, and rest periods during working time, and provides information about the impact of working time arrangements on the health, safety and family responsibilities of employees (South Africa, 1997 and 1998). The COP indicates that shift roster design must be sensitive to the impact on employees and their families; and information about this can be obtained during consultations, negotiations, or questionnaires circulated to employees. Employee preferences for different shift system elements, health and safety impacts, work-related aspects, transport options, and childcare needs may be considered.

Numerous recommendations relating to shift arrangements and roster design are provided in the COP, including the following:

- Overtime should be avoided;
- Shift changeovers should involve overlap of crews (where appropriate);
- Shift schedules should be distributed with reasonable notice;
- Special needs of workers should be considered;

- The frequency of work at night, and on weekends and public holidays should be limited;
- The frequency of shift rotation should account for difficulties in worker adaptation to night work;
- Shift should preferably be rotated in a forward direction, while considering employee preferences, local conditions, and the need to schedule long periods of rest after night shifts;
- Night shifts should not be longer than morning and afternoon shifts, long night shifts (i.e. hours substantially longer than 8 hours) should be reviewed to avoid excessive fatigue, and successive long night shifts should be avoided;
- Safety-critical tasks should not be undertaken when employees are likely to be fatigued;
- Rest periods should be scheduled to fall on weekends a minimum number of times in a given timeframe; and
- Rest breaks during the shift and rotation should be adapted according to the workload, such as for employees involved in physically and mentally strenuous work, repetitive movement, monotonous work, and for shifts longer than 8 hours.

Additionally, the working environment and management services should be considered. For example, the lighting and heating (or cooling) should be adequate for the health, safety, and comfort of the workers. Appropriate management services for employees working outside of ordinary hours should be available, such as: first aid, safety supervision, occupational health, emergency services, security, administrative services, transport, eating facilities, and change-rooms. Employees working night shifts should also be able to participate in training and education, and trade union or committee activities (South Africa, 1998).

Employees are entitled to medical examinations when commencing regular night work and at regular intervals thereafter, as indicated in Section 13 of the MSHA (South Africa, 1996). These examinations should include difficulties that the employee might have in adapting to night work, sleep disorders or sleep deprivation, stresses, other health problems, use of medication, diet, and the use of caffeine, alcohol and cigarettes (South Africa, 1998). Information should be provided about strategies that might assist the employee to cope with shift work, both at work and at home, such as maintaining regular sleep routines, blocking out noise and light when sleeping during the day, healthy diets, and exercise and relaxation (South Africa, 1998).

2.3. Fatigue and sleep

Fatigue is an occupational health and safety hazard, and is a causal or contributing factor to many incidents, accidents and injuries in the mining industry (Hodgskiss *et al.*, 2015; Pelders and Nelson, 2019a; Schutte, 2010; Theron, 2014). Fatigue risk is inherent in shift work and work that is physically or mentally demanding, repetitive, or requires vigilance (Schutte, 2010). There are numerous different definitions of fatigue, which include, for example: "...reduced mental and physical functioning caused by sleep deprivation and/or being awake during normal sleep hours" (South Africa, 2014, p5); and "...a state of impaired mental and/or physical performance and lowered alertness arising as a result of or a combination of hard physical and mental work, health and psychosocial factors or inadequate restorative sleep" (Schutte, 2010, p53).

2.3.1. Causes and consequences of fatigue

High levels of fatigue cause reduced performance and productivity, and increased risk of accidents and injuries (South Africa, 2014; Schutte, 2010; Theron, 2014). Fatigue results in impaired attention, alertness, concentration, coordination, reaction times, memory, decision-making ability, communication, judgement, creativity, motivation, and mood, and increased error rates (Bates, 2009; Pelders and Nelson, 2019a; Schutte, 2010; Theron, 2014). Fatigue and sleep loss can also result in health problems, including heart disease, hypertension, obesity, diabetes, digestive problems, reduced immune system function, cognitive dysfunctions, reduced learning ability, and mental illness, such as anxiety and depression (Pelders and Nelson, 2019a; Pfeifer, 2017; Schutte, 2010; Theron, 2014).

Total worker fatigue usually results from a combination of factors relating to work-time arrangements, work and environmental factors, and personal factors (South Africa, 2014; Schutte, 2010). Work-related issues include work time arrangements, high physical workloads, temperature extremes, excessive noise, work stress, and poor ergonomic design of workstations and equipment (South Africa, 2014). Fatigue may result from extended work hours and prolonged periods of physical and/or mental exertion without sufficient time to rest and recover (South Africa, 2014). Mental or physical demands include repetitive or monotonous work, sustained effort, and complex tasks (South Africa, 2014). Fatigue is also associated with long periods of time awake, insufficient opportunities for sleep, failure to use available sleep opportunities, poor quality sleep or the effects of sleep disorders, and medical conditions or pharmaceuticals which reduce sleep or increase sleepiness (South Africa, 2014). These medical conditions and disorders include sleep apnoea, restless leg syndrome, chronic fatigue syndrome, chronic pain, tuberculosis, HIV/AIDS, heart problems, and thyroid disorders (South Africa, 2014; Theron, 2014). Other factors that can contribute to fatigue include living conditions, commuting times, lifestyle related causes, such as poor diet or nutrition, a lack of exercise, activities outside of work and family commitments, drug and alcohol use, and psychological conditions (Pelders and Nelson, 2019a; South Africa, 2014; Theron, 2014). Psychological causes of fatigue include depression, anxiety, stress, and grief (Theron, 2014).

Further personal characteristics, such as demographics, socioeconomic status, and chronotype (morningness or eveningness), could also be associated with fatigue. In terms of gender, some studies have found fatigue to be higher in females than in males. Furthermore, previous studies have found that females, on average, sleep longer than males (e.g. Kalmbach *et al.*, 2018; Szalontai, 2006). Relating to age, Härmä *et al.* (2018) found that workers aged 50 years and older appeared to be at higher risk of fatigue than the younger workers in the study. In terms of socioeconomics, workers in South Africa that were more educated and those with higher wages have been found to have lower daily sleep times than those that were less educated or had lower wages (Szalontai, 2006). Szalontai (2006) noted that sleep time may vary as a result of economic incentives that compete for time. These findings are in line with previous international research findings (Szalontai, 2006). Countries with higher per capita incomes are reported to have lower average daily sleep times than those with lower per capita incomes, including South Africa (Szalontai, 2006). In a South African time use survey, the average time spent on sleep and sleep-related activities was 573 minutes per day (Szalontai, 2006). Additionally, the study revealed that people living in rural areas, on average, slept less than those living in a formal urban area. Lower sleep times and higher sleeplessness have also been

reported for those with higher general stress, lower regional unemployment rates, more educated people, fulltime employed workers, for shift-workers, and for higher household income classes (Pfeifer, 2017).

2.3.2. *Fatigue in the South African mining sector*

Theron (2014, p21) considers a number of aspects, including accommodation, transport, and socioeconomic factors, associated with being a mine worker in South Africa. A typical scenario was presented, as follows:

- “Predominantly the employee could stay in an informal settlement, facing hot summers and cold winters, without the basic needs like running tap water (warm or cold), sanitation or electricity. The accommodation (mostly single or double room) is usually shared with various family members and children.
- The employee could probably be the only breadwinner in the family.
- The employee’s nutrition would be based on the basic need to survive with food prepared in the most primitive way. The luxury of multiple meals per day does not exist.
- The employee’s day usually starts at 3am to catch...the first public transport to work. There could be various transfer points between the various standard routes before actually getting to work.
- The employee would clock in at work at around 6am, where the actual shift for the day would start.
- At the end of the shift, the employee will have to wait for available public transport to take him/her back home.
- The employee could arrive home at 5pm.
- Thus a normal working day from going to work to arriving back at home could be 15 hours.
- If the employee is a female, she would probably still have to perform the household duties.”

In a study by Hodgskiss *et al.* (2015), fatigue was a commonly mentioned safety hazard in the South African mining industry. Questionnaires were completed by 875 mine workers, and 31% of the respondents indicated having occasionally fallen asleep at work, and 15% had unintentionally fallen asleep while operating machinery in the previous year. These variables were positively correlated with sleepiness at work, and having been involved in an accident at work in the previous year. Over half (52%) usually received less than 6 hours of sleep in the 24 hours before a work shift.

Findings from interviews and focus group discussions that were held indicated that fatigue was attributed to various factors, including “physically demanding work, shift configurations, travelling distances to work, health, medication, diet, hangovers from alcohol use the previous night, potentially poor conditions in which to sleep, and psychological problems” (Hodgskiss *et al.*, 2015, p79). Long work hours, night shift work, a lack of time between shifts to get adequate sleep, and long walking distances and heat in underground workplaces, were potential causes of fatigue noted by the participating mine workers. Workers also often worked overtime to reach targets and obtain production bonuses. Inadequate sleep could also be caused by living conditions, as a result of factors such as noise, overcrowding, or exposure to the elements, and

long distances travelled to get to work. Stress was another cause of sleep disturbances, fatigue, and safety problems at work, and was primarily attributed to financial issues. Family responsibilities were further indicated as potential contributors to fatigue. Fatigue could further affect workers' health and well-being.

Participants in the study by Hodgskiss *et al.* (2015) suggested that facilitated transport, or improved transport conditions, especially when workers lived far from the mines, would assist to reduce fatigue. Other recommendations included improved nutrition (such as by lifestyle changes and/or the supply of energy drinks or nutrition at work), fulfilment of basic socioeconomic and living condition needs, increased awareness, wellness campaigns, and fatigue management programmes. Furthermore, increased mechanisation was another potential solution, as it would make mining less physically demanding (Hodgskiss *et al.*, 2015).

In a study conducted at a platinum smelter in South Africa, factors associated with fatigue included overtime, shift work, high workloads, activities performed outside of work, younger age, race, housing tenure, poor diet, sleep disorders, high stress, and low job satisfaction (Pelders and Nelson, 2019a). In this study, 44% of the participants were classified as fatigued.

2.3.3. *The impact of transport and travelling time to and home from work*

Brovko *et al.* (2018) noted that further research was required to better understand the total amount of time taken from when mine workers leave home before work until returning home after work, as this would have an impact on aspects such as health, safety, absenteeism and fatigue. Rupprecht (2018) further identified absenteeism as a cause of lost conformant blasts, and attributed absenteeism to various aspects including: lengthy work hours that often prevented crew members from completing personal chores; fatigue that results from shift length and/or environmental conditions in the stope; month-end travelling to and from home; and time to travel from home to the mine and back again (which also leads to fatigue). Fatigue should also be discussed when people drive long distances following a shift (Theron, 2014).

Previous research has indicated negative effects of commuting on health and mental well-being (Pfeifer, 2017). Pfeifer (2017) noted that the relationship between commuting to work and sleep was a largely neglected area of research. Further research by Pfeifer revealed that workers with further commuting distances slept significantly less per night during the work week. However, workers with longer commuting distances slept for slightly longer during the weekend, which could be a result of compensating for sleep loss during the work week. The research revealed that every one kilometre distance from the place of residence to the workplace was, on average, correlated with 0.0035 hours less sleep per night during the work week. For example, those that commuted 50 km received 10.5 minutes less sleep per night than the sample mean. The effect of increased commuting distance on reduced sleep during the work week was more pronounced for men than for women and for full-time than for part-time workers (which included more women than men). Mean hours of sleep in this study was 6.78 hours during the work week, and 7.96 hours during the weekend.

Other previous literature has indicated that workers with longer commutes were less productive (van Ommeren and Gutierrez-i-Puigarnau, 2009). Reasons for this reduced productivity at work could include arriving later or leaving earlier, lower effort levels, and

increased absenteeism. Absenteeism could result from poor health, which could result from high levels of stress associated with long commutes, or because of shirking, and the associated benefits of extra free time and lower travelling costs (van Ommeren and Gutierrez-i-Puigarnau, 2009). In the study by van Ommeren and Gutierrez-i-Puigarnau (2009) the average number of days absent in the previous year was 8, and increased commuting distance was significantly associated with increased number of days absent. It was indicated, for example, that number of days absent was 12% higher for workers with a one-way commuting distance of 40 km than for those with a commuting distance of 10 km (van Ommeren and Gutierrez-i-Puigarnau, 2009). The results were similar for males and females, and for when controlling for health indicators or not.

Another study previously conducted at eight mines in the South African mining industry, included an assessment of transport types and commuting times of mine workers (Hodgskiss *et al.*, 2015; Pelders and Nelson, 2019b). Some of the mines provided transport, or transport subsidies, to their workers. Public transport, such as buses and minibus taxis, were the most commonly reported form of transport (used by 22% and 21% of the participating mine workers, respectively), followed by company transport (19%), private vehicles (16%) or lift clubs (5%), and walking (14%), or a combination of the above (3%). In terms of commuting time, Hodgskiss *et al.* (2015) reported that 56% of the participants took less than half an hour to travel to or home from work, 34% took between 30 minutes and an hour, while 10% took longer than one hour. As expected, the distance of viable housing options from the mines affected travelling distances and time taken to get to and home from work. Transport was reported to be a common problem for the mine workers. Concerns relating to transport to and from the mines were poor road conditions, which could lead to accidents, and crime, especially for those who walked to or home from work or to access transport services. The cost of travelling was also sometimes a challenge for the workers. Additionally, in the study, transport type and travelling time were significantly associated with subjective sleepiness of the participants (Hodgskiss *et al.*, 2015).

The travelling times of migrant workers should also be considered in relation to shift cycles and fatigue of mine workers in South Africa. “To further reduce the impacts of the migrant labour system that the industry has employed for the past 130 years, the industry needs to look at shift patterns and transport for miners whose families still reside elsewhere, and...better housing around the mines...” (Sanqu, 2016, p6). The proportion of the local workforce in the mining industry is increasing; however there are still many migrant labourers that live close to the mine when working, but have homes and families in labour-sending areas (Sanqu, 2016).

2.3.4. Fatigue management

Fatigue management is a joint responsibility of employers and employees, and active participation from all stakeholders should be encouraged (South Africa, 2014; Schutte, 2010; Theron, 2014). Employers should ensure that work is scheduled to allow for adequate recovery, provide education on work-related risks such as fatigue, and conduct risk assessments to allow for the control of tasks and conditions that could negatively interact with fatigue (Baulk *et al.*, 2009). Meanwhile, employees have the responsibility to rest adequately when not at work, and to report fatigue related hazards (Baulk *et al.*, 2009).

A comprehensive and holistic approach to fatigue management is required, and fatigue management programmes should address the unique needs of the operation (Schutte, 2010). Fatigue management plans should aim to manage the risk of fatigue, and maintain or enhance safety, performance, and productivity in the workplace (South Africa, 2014; Schutte, 2010). The recommended process for developing and maintaining a successful fatigue management plan involves: securing and maintaining management commitment; establishing a fatigue management committee; developing policy and programmes; managing fatigue; communicating the policy and fatigue management plan; information, education, and communication; and monitoring, reviewing, and modifying (South Africa, 2014; Schutte, 2010).

Effective fatigue management involves optimal shift system and roster design, the ergonomic design of workplaces and tasks, management processes for monitoring and controlling potential fatigue, along with aspects relating to employee fitness for work, education and training, and employee assistance programmes (Schutte, 2010). Both leading indicators and outcome measures of fatigue should be considered in fatigue management plans (South Africa, 2014; Schutte, 2010). Leading indicators include, for example, the number of individuals with sleeping disorders, or who self-report fatigue at work. Outcome measures include incident or accident rates, near-misses and safety-critical events, equipment damage, employee feedback, absenteeism, and staff turnover (South Africa, 2014; Schutte, 2010).

Various potential control mechanisms could be employed to manage fatigue risks. Some of these, listed in South Africa (2014), include:

- Review and amend policies and procedures;
- Optimally adjust shift rosters with the support of employees, using the 'bio-roster' concept (i.e. biologically compatible roster), while considering employee needs for family and community involvement;
- Control the working environment to reduce factors that contribute to fatigue e.g. physical workload, noise, vibration, temperature, lighting etc.;
- Implement systems or technology to monitor performance of workers in safety-critical positions;
- Conduct regular medical examinations and certification of fitness, and provide health-related education and information; and
- Ensure availability of drinking water, and supply meals to reduce fatigue and ill-health.

2.4. Conclusion

The use of shift cycles in the mining industry has an impact on the health, safety, and social wellbeing of employees, particularly because it can result in fatigue and social disruption. The effects of fatigue include errors, accidents, poor health, absenteeism, reduced productivity, and possible lost conformant blasts. Fatigue can arise because of work time arrangements, mental and/or physical workloads, the work environment, and personal factors, such as inadequate sleep, medical conditions, and lifestyle related factors. The time taken for employees to travel to and home from work can also contribute to fatigue and absenteeism. Fatigue management requires a holistic approach, which addresses specific needs of each operation, and involves optimal shift scheduling that considers employee needs.

2.5. Recommendations

A number of fatigue-related factors to consider relating to shift cycles in the mining industry were noted in this literature review, and it is recommended that these factors be considered when scheduling shift cycles. Associated factors to consider are summarised as follows:

- Limit work at night, on weekends, and on public holidays;
- Avoid excessive regular overtime and on-call work;
- Avoid backward rotating shifts (e.g. night to afternoon to morning);
- Avoid shift rosters with irregular or unpredictable patterns;
- Avoid working numerous consecutive shifts (e.g. more than four 12-hour night shifts);
- Allow for continuous sleep of seven to eight hours in each 24 hour period;
- Provide at least 36 hours off following a period of night shift work;
- Safety critical tasks should not be undertaken when employees are likely to be fatigued (e.g. during night shifts, 12 hour shifts, or when performing work with high physical or mental demands, or repetitive or monotonous work);
- Ensure appropriate rest breaks within each shift;
- Consider employee preferences and needs in shift schedule design;
- Work environment factors such as lighting, noise, and temperature should be appropriate for worker health, safety, and comfort;
- Appropriate management services should be available to those working outside of ordinary hours;
- Ensure availability of appropriate resources e.g. staffing and equipment;
- Medical conditions and psychological issues are associated with fatigue, and should be managed in the context of shift work;
- Poor nutrition contributes to fatigue, therefore consider the supply of meals or supplements for workers;
- Consider the living conditions of workers, as aspects such as exposure to noise and temperature extremes contributes to fatigue;
- Commuting time impacts on fatigue, accident risk, and absenteeism – the regulation or provision of transport could help to mitigate risk; and
- Fatigue management programmes should address the unique conditions of each operation.

Further aspects relating to shift cycles warrant consideration. These include aspects such as productivity, available face time, supervision, skills, logistics, and maintenance. A number of these aspects are covered in the following chapter (Milestone 3), which is a literature review about maximising asset utilisation, with a focus on shift cycles. Further information about different shift cycles in use locally and globally is also provided.

3. Optimising productivity with a focus on shift cycles

3.1. Introduction

The productivity in narrow reef hard rock underground gold and platinum mines has been declining over the past few years. For example, South Africa was the number one gold producer until 2009 when that position was taken by China. As shown in Table 2, in 2009, South Africa was ranked number one in gold reserves; however, it was ranked number five in production.

Table 2: South African mineral endowment 2009/2010 (DMR, 2017)

MINERAL	Unit	RESERVES			PRODUCTION 2009			LIFE
		Mass	%World	Rank	Mass	%World	Rank	Years
Gold	t	6000	12.7	1	197	7.8	5	30
PGMs	t	70000	87.7	1	271	58.7	1	258

Neingo and Tholana (2016) highlighted that the decline in mining productivity can be attributed to a number of factors such as increasing mining depth, depletion of high grade ores, fluctuating commodity prices and labour unrest. Mining productivity can be measured in a variety of ways such as unit cost, output per employee and output per unit capital equipment. Most narrow reef, underground platinum and gold mines in South Africa utilise conventional labour intensive mining methods which are dependent on drilling and blasting to break the rock. Blasting requires a re-entry period of between one and four hours to allow the harmful blasting gases to clear before the next shift can resume work (Brake, 2015). The mines are also getting deeper and the working faces are moving further away from the existing shafts, resulting in employees spending a significant portion of the available shift time travelling to and from the work face. Over the years, there has also been an increase in occupational health and safety (OHS) requirements before and during the shift, such as safety talks, early entry examinations and making safe and continuous risk assessments. Resultantly, the workforce has inadequate available face time to meet all the production targets. The constraint is further exacerbated by the hot and humid environmental conditions underground which render the workforce more vulnerable to fatigue, resulting in lower productivity as noted by Neingo and Tholana (2016).

Neingo and Cawood (2014) challenged the mining industry to continually explore innovative ways of optimising productivity, through optimal utilisation of resources such as labour, materials, equipment and funding. In order to improve the viability (improve OHS, reduce operational costs and increase productivity) of the narrow reef underground hard rock mines, it is essential to investigate new approaches to optimise the utilisation of these resources. One such approach is the optimisation of shift cycles (Rupprecht, 2016).

This literature review seeks to review the methodologies used to maximise the utilisation of resources with a focus on shift cycles, in mining and other heavy-duty industries, locally and internationally. Different shift cycles in use globally are explored as well as the impact of other factors such as ancillary activities, available face time, supervision, skills, logistics, and maintenance.

3.2. Shift cycles

Globally, there is a rising demand for 24-hour operations in industries such as mining, production factories, security, transportation, insurance, communications, health and other service industries. This demand is against the backdrop of the need by companies to improve key business performance areas such productivity, operational costs, OHS and market footprints. In order to attain 24-hour operations, the use of shift work, in various configurations is required. Merkus et al. (2012: p702) defines shift work as, “regular employment outside the hours 06:00–18:00, in schedules that include evening and/or night shifts (including permanent night shift).” Shift work can be organised in different ways, depending on the arrangement of several components, including the length of the shift, rest breaks and continuous shifts (Dall’Ora et al., 2016). Regular employment implies working only one shift, while irregular employment includes rotating shifts that involve working two or three shifts, whether weekends are counted in or not (Eurofound, 2015). Rotating shifts systems may follow a clockwise (CW) (i.e. forward) direction of rotation (for example day, afternoon, night) or may follow a counter-clockwise (CCW) (i.e. backward) direction of rotation (for example day, night, afternoon) (Shiffer et al., 2018).

In response to the global market competition and economic pressures, organisations have also resorted to the use of extended shifts, longer than the conventional 8 hours (Baker et al., 2003b). The advantages of extended shifts may include reduced sick leave, improved communication at shift changeover, improved productivity and morale (Baker et al., 2003b). However, factors such as fatigue, increased sleepiness, impaired performance and increased rate of OHS incidents were identified as areas of concern associated with extended hours of work (Baker et al., 2003b). Dall’Ora et al. (2016) noted that most companies have embraced the zero harm objective, however, employees are expected to work productively while maintaining their safety and well-being. Since shift work is identified as one of the components of work organisations that affect the balance between efficiency and well-being of employees, it is imperative to understand the implications of different shift cycles on employees in order to make sure that they work safely and productively (Dall’Ora et al., 2016).

Shift work is commonly practised in the mining industry, in South Africa and globally. Some mines operate continuously (24 hours per day and 7 days per week). A trend towards the use of 12-hour long shifts has also increased in the mining industry (Stenzel, 2002). In order for mining to remain viable, it is important to maintain a healthy and safe working environment all the times. One of the criteria used by organisations to improve performance and well-being of employees is by focusing on important aspects of work design such as shift work. Shift cycles must be designed to minimise fatigue and optimise productivity (Smith et al., 1998).

Ngobese (2017) suggested that changing shift cycles might assist mines to optimise productivity, hence improving their viability. Whether the decision is to increase or reduce the hours per shift, the maximum of 45 working hours per week stipulated by the Basic Conditions of Employment Act (BCEA) must be taken into consideration. Designing an optimum shift cycle requires careful evaluation of different options and factors such as fatigue, productivity and legislative requirements (Pickering et al., 2010). There are various shift options that can be considered in order to maximise asset utilisation to increase productivity. Applicable shift

rosters include, but are not limited to, 12-hour shift rosters, two 10-hour shifts per day, three 8-hour shifts per day, 7 days per week and the fly in/fly out (FIFO) system.

3.2.1. Employee participation in shift design

Changes in shift cycles at any workplace, is a significant change, requiring good change management including maximum buy-in, commitment and support from all the interested and affected parties (stakeholders). Apart from producing an all-encompassing shift cycle, this has the impact of creating a sense of ownership on the outcome (shift cycle), thus facilitating smoother adoption and implementation. Working hour arrangements that employees did not have a say in during the design process, are unlikely to serve their interests and will therefore probably fail (Peetz & Murray, 2010). A good shift design can be achieved by consulting with the stakeholders demonstrating the benefits (such as improved OHS, productivity and increased time off work to pursue personal errands) of changing from the old to new shift cycle arrangements.

3.2.2. Impact of shift work characteristics on employee job performance, absenteeism and well-being

In a study to identify characteristics of shift work that have an effect on employee's performance and well-being, Dall'Ora et al. (2016) discovered that a variety of shift work characteristics are associated with compromising employees' performance and well-being. Findings highlighted the following:

- Shifts of 12 hours or more are associated with jeopardised outcomes – various studies have highlighted that longer shifts impact negatively on workers' social lives. Employees struggle to maintain a satisfactory balance between work and personal life. If the degree of work/life conflict is allowed to become too much of a problem, it can be harmful to psychological health and may lead to alienation, distraction and disengagement (Brown et al., 2010);
- Working rotating shifts was associated with worse job performance outcomes – this echoes with the statement by Jacobsen and Fjeldbraaten (2018: p1146) which highlighted that working rotating shifts including night shift impacts employees' health negatively and that may lead to poor job performance outcomes;
- Fixed night shifts enabled better resynchronisation but were associated with reduced job satisfaction; and
- Timely breaks impacted positively on fatigue and employee alertness.

On the contrary, some authors have reported improved health and reduced feelings of tiredness, leading to lower rates of absenteeism, as a result of changing from 8-hour to 12-hour shifts (e.g. Baker et al., 2003a; Smith et al., 1998). The 12-hour shift was associated with a longer block of time away from work, which allowed more recovery from work, resulting in increased well-being (Baker et al., 2003a). However, a concern was expressed about the issue of overtime with 12-hour shift systems (Smith et al., 1998). Irregularly scheduled overtime at the end of a regular 12-hour shift extends hours of work, and this may interfere with employees' commitment to family time. Dissatisfaction with work hours may result in higher absenteeism (Baker et al., 2003a). Absenteeism can also be a mechanism of withdrawal from work if the employees are discontent with a new shift cycle (Baker et al., 2003a). From the literature, it is apparent that the

implementation of longer shifts (such as 12-hour long shifts), without any overtime will potentially reduce absenteeism and result in improved productivity (Baker et al., 2003a).

3.2.3. Shift work, work-family conflict, perceived health and absenteeism

Absenteeism or lost days of work affects productivity and effectiveness, and also imposes extra costs to an organisation (Jacobsen & Fjeldbraaten, 2018). Although the literature reported on an increased number of lost days of work due to sickness absence in many countries (Livanos & Zangelidis, 2013), there were only a few studies that directly linked shift work to sickness absence (Jacobsen & Fjeldbraaten, 2018; Merkus et al., 2012). Shift work was linked to sickness absence by two mediators: perceived health and work family conflict (Jacobsen & Fjeldbraaten, 2018). The argument is that shift work affects health as well as making the balance between work and family life difficult to maintain; both in turn result in higher sickness absence. Absence is then used as a coping mechanism to deal with the conflict of work-family imbalances and health if it resulted from health problems induced by shift work. If the organisation has less control on understanding why the rate of absenteeism is high, the mechanisms become easier for the employees to use (Jacobsen & Fjeldbraaten, 2018).

3.2.4. Shift work, hierarchical positions and absenteeism

The literature further reported on the difference in the pattern of sickness absence relating to hierarchical positions. Sickness-related absence was prevalent in the lower level workforce compared to the leadership. This could be because most of the leaders are less involved in shift work compared to the rest of the workforce (Clausen et al., 2014). Workers in leadership positions will try to avoid unnecessary absenteeism at all costs as they have more ownership of the business and are charged with the responsibility of meeting safety and productivity targets.

3.2.5. Shift work, gender differences and absenteeism

Sterud (2014) highlighted the link between gender and sickness absence and women were reported to have a higher absence rate than men. Further studies also indicated that women working shifts complain of tiredness more than men, resulting in higher sickness absence compared to men (Szubert et al., 2016). Furthermore, women working shifts may experience more work-family conflict related challenges than men, as women generally have more family responsibilities at home. According to the Department of Mineral Resources (DMR), the number of women in the mining industry across all levels is more than 10% of the total workforce (DMR, 2014). However, the introduction of women in the mining industry which was historically male dominated, resulted in new challenges as women have unique health, safety, security and social needs (Zungu, 2014). Thus consideration of the health, safety, security and social needs of both female and male employees must be taken into consideration when designing shift cycles.

3.2.6. Shift work and supervision

In analysing the association between shift work and organisational factors, Gómez-García et al. (2016) discovered that night shift nurses had worse perceptions of the nurse manager's ability, leadership and support, highlighting the lack of effective supervision during night shifts. Only a few managers are allocated to work nightshifts. Reduced levels of supervision at night may lead

to employees feeling unsupported. Effective supervision is described as critical to provide interpersonal and instrumental support, which results in a more supportive and positive team environment (Pisarski et al., 2008). Ineffective supervision may result in reduced productivity and poor OHS performance, thus it is critical to ensure that sufficient supervisory capability is provided to all shifts, in order for operations to remain optimal.

3.2.7. Work schedules, education, training and employment

Extended shifts require the production crews to be cycled on long sequences of day shifts and night shifts, for example, three production crews may be cycled as follows: 7 days on day shift, 7 days on night shift and 7 days off duty. Various authors discussed the impact of long sequences of day shifts and night shifts on the personal development of the employees. Extended shifts may inhibit professional growth of employees due to limited on-the-job training opportunities and difficulties of finding time and energy to study (Brown et al., 2010; Smith et al., 1998).

The use of extended shifts will reduce the number of daily shift requirements from three to two, but will increase the number of production crews from two to at least three. This will cumulatively result in increased labour requirements, hence increased employment. Increased available face time may allow each of the production crews to effectively operate with fewer number of employees, which can be effectively supervised. Potential benefits of extended shifts such as improved supervision, attendance, morale and communication during shift changeover will result in improved safety and productivity (Baker et al. 2003a).

3.2.8. Social support and culture

Brown et al. (2010) noted the importance of establishing relevant “social support structures”, to enable effective management of the negative consequences associated with strenuous and unsocial work schedules associated with extended shifts. The availability of good social support structures within the workplace will boost the team morale and spirit, thus assisting the crews to cope with the demands of working schedules. The authors further highlighted that poor communication and limited social support from colleagues led to low levels of morale, which resulted in a lack of enjoyment and the ability to cope.

3.2.9. Comparing shift cycles at South African mining sites

i. Mine A

A comparison of shift cycles at different South African mines was completed. To maintain the confidentiality of the operations, the mines are identified as Mines A, B and C. Mine A is described as a continuous (full calendar) operation, comprising of two 10.5-hour shifts per day. Three production crews are cycled on a 14 – 7 day system (14 days on shift and 7 days off). A crew works morning shifts for 7 days and then changes over to night shift for 7 days. A new crew then cycles into day shift and the third crew goes off duty (Figure 8). This offers the crew cycling from day shift a 24-hour break before they start the night shift. Moreover, the shift arrangement potentially offers a healthy work-life balance, by creating sufficient time to perform work as well as freeing up time for the workforce to attend to private life requirements.

This might potentially address challenges like fatigue, absenteeism and low productivity (Mabuza, 2007).

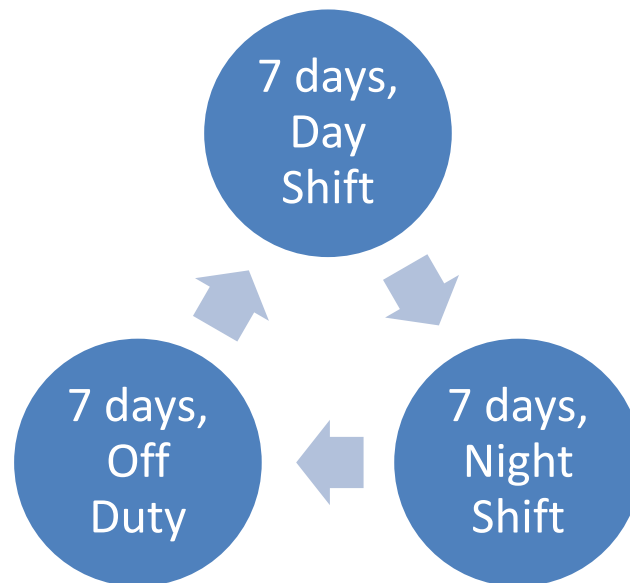


Figure 8: Illustration of Mine A shift cycle arrangement

ii. Mine B

Mine B is a non-continuous operation, comprising of two 10.5 hour shifts per day. Three production teams are cycled, as illustrated in Figure 9. No mining related work takes place on Sundays and every employee has an opportunity to have a 7 day break after every second week, thus people have time to rest and attend to do their personal errands.

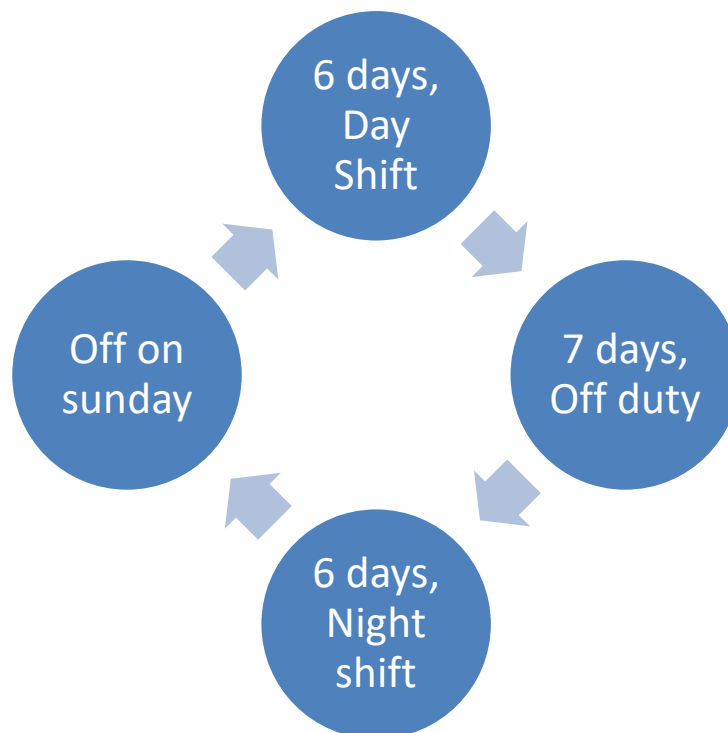


Figure 9: Illustration of Mine B shift cycle arrangement

According to Theron (2014) the shift cycles at Mine B, as illustrated in Table 3, were designed while taking into consideration operational requirements and fatigue risk levels. Theron (2014) described the fatigue-based risk management approach, which was also informed by the comprehensive checklist provided in the mandatory code of practice (COP) on fatigue management (DMR16/3/2/4-B2). Operations, shift and job based risks were identified and assessed, and measures to eliminate or minimise the risk were developed. The risks were identified under the following categories:

- Mental and physical demands of work (monotony, mental and physical effort etc.);
- Work scheduling and planning for night work (shift end time, shift length, sequential night shifts, breaks etc.);
- Work scheduling and planning for shift work (length, time, speed and direction of shift etc.); and
- Work scheduling and planning with consideration of working hours and work related travelling.

Theron (2014) recommended that an effective shift cycle must have a risk rating of low to medium. A cost benefit analysis was also presented to all mine stakeholders demonstrating the benefits of the proposed shift to conventional work schedules. This was critical to secure the stakeholders' buy-in, support and commitment to facilitate the successful implementation of the shift schedule.

Table 3: Shift cycles at Mine B (Theron, 2014)

Mining	Processing
2 Shift Cycles <ul style="list-style-type: none"> • Cycle workers (10h30) • 5 day workers (9 hours) 	2 Shift Cycles (Full-CO) <ul style="list-style-type: none"> • Cycle workers (12h00) • 5 day workers (9 hours)
Cycle workers <ul style="list-style-type: none"> • Crew A,B,C • 1st week N/s (6days) • 2nd week D/s (6 days) • 3rd week Off (7days) • No work on Sunday 	Cycle workers <ul style="list-style-type: none"> • Crew A,B,C • 4 x4 shift cycle • 2 days D/s • 1 day (24 hour break) • 2 days N/s • 4 days off
Critical success factors <ul style="list-style-type: none"> • Minimum disturbance on circadian clock • Mid shift fatigue system • Transport arrangements • Family time social benefits 	Critical success factors <ul style="list-style-type: none"> • Minimum disturbance on circadian clock • Mid shift fatigue system

Table 4 provides a comparison between the shift cycles at Mine A and Mine B. As shown in the table, the continuous operation as practised at Mine A has a higher number of employee shifts per month and asset utilisation days per month compared to Mine B. The Mine B shift cycle arrangement potentially results in minimum fatigue to the workforce. A comparison of the productivity and OHS performance between the two operations might provide insight into some of the crucial factors to consider when optimising shift cycles.

Table 4: Comparison between the shift cycles at Mines A and B

Mine	Shift cycle	Employee shifts pm	Asset utilisation days pm	Possible shifts pa	Employee shifts pa	Assets utilisation days pa
Mine B	6-6-7	18	26	313	210	313
Mine A	7-7-7	21	28	365	246	365

iii. Mine C

Stenzel (2002) reported that Mine C was requested to increase their production output from 13.20 million tons per annum to 15.12 million tons per annum in 2001. Two options were considered as follows:

- Buying new equipment fleet; and
- Increasing the labour force to enable Full Calendar Operations (FULCO) / Continuous Operations (CONOPS).

	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S
Crew 1	D	D	D	D	O	O	O	O	O	A	A	A	A	A	A	A	O	N	N	N	N
Crew 2	A	A	O	N	N	N	N	N	N	N	O	D	D	D	D	D	D	O	O	O	O
Crew 3	N	N	N	O	D	D	D	D	D	D	D	O	O	O	O	O	A	A	A	A	A
Crew 4	O	O	A	A	A	A	A	A	A	A	O	N	N	N	N	N	N	O	D	D	D

D (Day) Shift	06:00	14:30
A (Afternoon) Shift	14:00	22:30
N (Night) Shift	22:00	06:30
O (Off)	22:00	06:30

Figure 10: 3x8 hour shift cycle utilising 4 crews (Stenzel, 2002)

Stenzel (2002) reported that the feasibility study that was conducted at the mine revealed that changing the shift roster, particularly changing to a continuous operation and increasing the size of the workforce, proved to be more viable than investing in new equipment. Further details of the feasibility study could not be found. Stenzel (2002) added that the mine engaged and consulted with all stakeholders (unions, workforce and government) for 6 months and then changed to continuous operations (3 x 8-hour shifts per day). The 3x8 hour shift cycle utilising four crews is illustrated in Figure 10. The adoption of a continuous operation resulted in the realisation of full production of 15.12 million tons per annum, 1 year ahead of target.

Stenzel (2002) further noted that although the mine achieved the production and financial targets post implementation of the 3x8 shift cycle system, OHS performance deteriorated significantly. To this end, the mine made efforts to learn from other international continuous operations. The mine learnt that continuous operations in Australia were using 2x12 hour rosters compared to 3x8 hour rosters. The mine also consulted Circadian Technologies which had conducted extensive studies on 4 crew shift rosters. From the analysis, it was apparent that the 2x12 hour roster optimised both production and OHS performance as compared to the 3x8 roster, which only optimised production. Again the mine began engagements with all stakeholders on the possible shift from 3x8 hour to 2x12 hour long shifts. After about 3 months

of engagements, the mine adopted 12-hour shifts using the 4 on 4 off (4x4) roster to work continuously. Figure 11 is an illustration of the shift cycle followed by each crew.

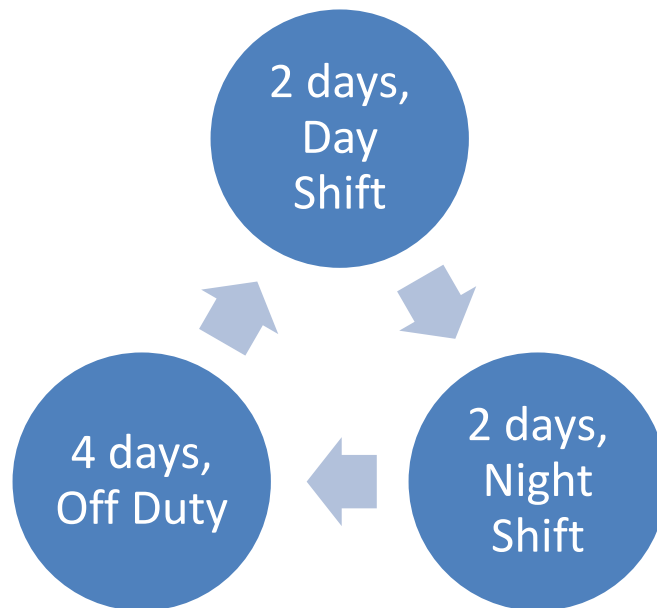


Figure 11: Illustration of the 4x4 shift cycle arrangement

Stenzel (2002) listed the following as disadvantages of three 8-hour shifts as observed at the mine:

- High levels of family responsibility and casual leave;
- High accidents rates mainly on the 6th night shift, as a result of working seven continuous night shifts during a roster cycle;
- About 6.25% of the shift time was lost daily as a result of changing shifts three times. The 8-hour shift system was problematic for the aged workforce as it did not give them enough rest. Studies have shown that with age the ability to work shifts deteriorates; and
- 8-hour shift roster did not have lunch break, which was against the stipulations of the legal requirements (BCEA).

According to Stenzel, the following advantages were observed after adopting the 12-hour shift roster:

- The 12-hour shift roster minimised the disturbance of the circadian rhythms, and thus resulted in improved OHS performance. The 4x4 roster had only two consecutive night shifts, hence reduced sleep deprivation;
- Absenteeism levels were significantly reduced as employees had more time to run personal errands during off days which come after every four days;
- Higher asset utilisation;
- Two shift changes per day resulted in fewer disruptions, thus 6.25% time savings. The ageing working force had more time to rest between shift cycles;
- The shift cycles allowed for the introduction of a 30 minute planned lunch break, with company provided meals. The planned lunch breaks resulted in minimal disruptions to production; and
- The productivity further increased by about 21%.

However, Stenzel (2002) highlighted some challenges as a result of implementation of the 4x4 shift cycles, such as reduced flexibility for training, difficulties if overtime work was required, and adjustments to line management.

3.2.10. Extended shifts (10 hour and 12 hour long shifts)

Extended (both 10 and 12 hour long shifts) shift rosters have become popular with shift workers because both rosters present the compressed working week (Smith et al., 1997), which can be defined as the system of working hours that exceed 45 ordinary hours in a week or more than five working days in a week (South Africa, 1998). Some of the benefits of the longer shifts reported by (Smith et al., 1997), also included:

- Longer shift times can allow more time for servicing shaft infrastructure. Sound maintenance, added to the reduced utilisation of the cage per day will improve the cage availability;
- 12 hour rosters significantly increases available face time, hence increased productivity, reduced errors and reduced lost blasts;
- Increased inter-crew coordination; and
- Longer breaks (off days) will give employees more time to rest and attend to their other social needs.

Although extended shift rosters have many advantages, there are still some disadvantages that come with the system, which include but are not limited to:

- Extended shifts might be unacceptable for some employees, such as those performing physically demanding work in unfavourable environmental (hot and humid) conditions found in conventional mine stopes, the elderly and those performing monotonous work;
- Extended time at work will significantly increase exposure to work related risk such as OHS incidents, fatigue and stress;
- Frequent disturbance of circadian rhythms. The body is required to adapt to new activity and sleep times every four days; and
- Workers may be prone to accidents as they return home after the shift. Safe driving becomes a concern for workers driving for more than an hour after completing the longer shift.

Proper work scheduling is critical for the realisation of full potential arising from the use of extended shifts. For instance, a mine having two extended shifts per day may benefit from blasting only once daily and having enough available working faces. This could allow for the face-to-face (hot seat) shift changeovers and associated benefits such as improved communication, increased available face time, reduced number of lost blasts and reduced work disruptions (Pickering et al, 2010). Hot sitting might not be feasible in certain conventional underground operations, due to extensive travelling distances. In these instances, arrangements can be made for the shift changeovers to be done at any convenient place along the travelling way.

3.3. Legislation

There are various regulations in place for ensuring safe and fair working conditions in the South African Mining Industry, such as the BCEA, Occupational Health and Safety Act (OHSA) and the Mine Health and Safety Act (MHSA). Shift cycles must be designed in a manner which enables the mines to meet production and OHS targets as well as comply with all legislative requirements.

The purpose of the BCEA is to advance economic development and social justice by fulfilling the primary objects of the BCEA which are: to give effect and regulate the right to fair labour practices conferred by the section (23) of the Constitution and to give effect to obligations incurred by the Republic as a member state of the International Labour Organisation (South Africa, 1997). The BCEA requires employees not to work for more than 45 hours a week or 9 hours in a day if an employee works for five days in a week. In cases where an employee works for more than five days a week, the employee can work 8 hours in a day. Section 4 of the Code of Good Practice, on the Arrangement of Working Time (The Code), states that the design of shift rosters must be sensitive to the impact of these rosters on employees and their families (South Africa, 1997).

Before changing a shift cycle the employer should consult, negotiate or circulate a questionnaire to the employees to find out the possible effects the change may have on employees. The Code further suggests that the employer may require the following information from employees in order to make an informed decision about changing shift rosters:

- The ranked preferences of employees for different shift systems by looking at:
 - Rate of rotation;
 - Shift length;
 - Extension of operation time;
 - Starting and finishing time of shift;
 - Weekends off;
 - Off duty periods.
- The pros and cons of the existing and proposed shift as per employees' views;
- The effects of both suggested and current shifts on the health and safety of employees;
- Security and transport issues/challenges that may arise for employees. These may include the availability, means and associated cost to safely commute from the employees' residences to work. The employee should still be able to do his/her work effectively upon getting to the workplace; and
- The childcare needs for the employees.

Mining is a hazardous occupation that requires the workforce to be physically, mentally and emotionally fit, in order to achieve zero harm production. Compromising safety or productivity is undesirable for the continued sustainability of the mining industry, thus the design of shift rosters should holistically optimise safety and productivity. The majority of mines operate night shifts and The Code makes the following provisions for night shift work:

- The duration of the night shift should not be longer than day and afternoon shifts (section 6.4 of The Code); and

- The design of the shift roster should take into account that employees need time to get used to night shift. Humans are naturally diurnal; therefore working night shift is against circadian rhythms (section 6.2 of The Code).

Moreover, section 10.4 of The Code requires the employer to ensure that afternoon and night shift workers have access to administrative services; this is to ensure that these workers do not have to use their off time to address administrative issues. If the shift change is frequent the necessity to avail these services is less than when the shift change is less frequent. Administrative services may include wages and personnel departments, and hiring additional personnel may be required to provide such services. In cases where there may be permanent night or afternoon shift workers, those workers should also have access to educational and training services and facilities (section 10.6 of The Code). Section 10.6 of The Code notes the need for employees to be able to be part of collective bargaining, trade union decisions, workplace forums activities and safety committees.

In terms of section 10.10 of The Code, when designing rosters rest periods should be included, with particular importance for employees who perform the following types of work:

- Physically and mentally strenuous work;
- Manual lifting;
- Work involving repetitive movement;
- Monotonous work; and
- Shifts longer than 8 hours.

3.4. Productivity

The productivity in the gold mining sector in South Africa has been decreasing significantly, as the mines are getting deeper and high grade deposits are being depleted. Neingo and Tholana (2016) described the South African underground gold mining industry as an industry which is characterised by inherent technical constraints such as narrow the stoping width (about 1 m), making mechanisation difficult and resulting in labour intensive mining operations. Musingwini (2014) suggested the need of optimising asset utilisation in order to derive optimal value from the remaining low-grade and deep lying deposits.

Neingo and Tholana (2016) further highlighted the importance of putting in place measures to ensure high labour availability and utilisation as the mining industry is more unionised. Labour productivity is affected by a number of factors such as available face time, operator efficiency, mechanical availability of the equipment and prevailing workplace temperature. Labour productivity is also affected by several human related factors which can be classified as follows:

- Labour availability;
- Labour - management relations;
- Labour - labour relations;
- The crew quality; and
- Organisational performance culture (Aljuhani, 2002; Roussos, 1996).

Roussos (1996) mentioned the lack of education among mine workers as one of the barriers to productivity as people with lower educational attainment have:

- Low literacy rates;
- A low skill base;
- Lack of understanding of business principles; and
- Lack of understanding of how workers fit into a productive workplace of why productivity is important.

The above-mentioned factors will potentially result in labour unrest as a result of lack of understanding between company goals and expectations of the employees. Roussos (1996) further argued that some cultures, languages, or values can also hinder productivity. These include, but are not limited to:

- The lack of common values;
- Different attitudes/cultures;
- Different political/ideological values and beliefs; and
- Linguistic barriers to effective communication.

Research conducted by Neingo and Tholana (2016) revealed high variances in the time workers are paid for and the actual productive time. They observed, from mines visited, that shorter effective shift time is caused by having longer meetings than planned (resulting in late starts), long travelling times to work stations, unauthorised breaks due to lack of discipline, and early work stoppages. The available face time has also been shortened by advancements in OHS practices such as early entry examination, making safe and continuous risk assessments. The declining productivity can rationally be attributed to the shorter available face time and increased workload for the same crew size. In order to improve productivity, it is critical to review the current work and shift schedules. This will ensure that the mines have the right size of the crew to complete the right work load within the right time.

3.4.1. Logistics

Deepmine research identified transportation as one of the key factors to efficient mining operations (Rupprecht et al., 2001). The research further revealed that in order to achieve safe, quality blasts every day, sufficient face time must be available so that the entire mining cycle can be completed in a shift. Rupprecht (2016) also emphasised that time must be available for unplanned activities to be completed within a shift cycle; and further acknowledged that for this to be successful, an efficient transportation system is required for the workforce to get to the face in less than one hour and suggested the use of 10 to 12 hours shifts that will ensure increased face time. The introduction of technology to expedite other OHS procedures such as early entry examination, barring, support and risk assessments may also potentially assist to increase the available face time for mining enough activities.

3.4.2. Maximum asset utilisation

In 2011 the Minerals Council of South Africa (formerly called the Chamber of Mines of South Africa), together with organised labour, commissioned the Sindisa Gold project. The aim of the project was to produce a collective agreement to prolong the life of the mines in the industry by optimising asset utilisation. The parties involved in the project included AngloGold Ashanti, Gold Fields, Harmony, National Union of Mineworkers (NUM), Solidarity and United Association

of South Africa (UASA). These parties agreed that in order to maximise asset utilisation the following principles must be achieved (Lazare, 2013):

- An increase in the number of annual productive working days;
- More productive blasts;
- Improved face advance per blast;
- Increased development rates; and
- Additional mineable face length.

The following guidelines were envisaged as principles that should be adopted when maximising labour utilisation (Lazare, 2013):

- Allowing mines to increase the number of production days per calendar year;
- Christmas break and public holidays remain – although this may be changed at mine level;
- Flexibility to work on Saturdays and Sundays;
- Working hours adjusted at operational level with regard to legislative requirements;
- Shifts not to exceed 12 hours crush-to-crush;
- Optimal calendar working arrangements to be determined at mine level; and
- There must be consensus/agreement amongst all stakeholders.

3.4.3. Mining processes and tasks

iv. Ancillary activities

There are a variety of factors that cause delays in a mining activity cycle. During the Sindisa project, time motion studies were conducted at three selected mines. Ancillary activities that caused delays were listed as indicated below (Lazare, 2013).

i. Cleaning task delays

In the three mines, the majority of the delays in cleaning were due to waiting for locomotives and hopper derailment. Other activities that caused delays included:

- Waiting for the crew at the face (late arrivals);
- Repairing mechanical loader hoses;
- Waiting for loco to fetch hopper;
- Congestion at the tip;
- Loader derailment;
- Air coupling came loose;
- Fixing fishplate;
- No compressed air;
- Waiting for support crew; and
- Work stopped due to temperature and ventilation challenges.

ii. Drilling and supporting task delays

The drilling and support delays were mainly due to ventilation interruptions in all the operations. Other activities that caused delays included:

- Waiting for equipment;
- Repairs on water pipe;
- Replacement of hydraulic pipes;

- Briefing on safety;
- Waiting for methanometer;
- Barred rock from face;
- Waiting for previous crew to finish;
- Waiting for drill rigs;
- Drillbit stuck/replacement;
- Power outage;
- Miner and shiftboss talks with the team;
- Waiting for miner;
- Drill rig with one boom only; and
- Adjusting motors.

Most of the identified bottlenecks can be eliminated by good practices such as good planning, work organisation, efficient communication strategy and sound maintenance practices. It is critical that a systems thinking approach be adopted, as optimising shift cycles alone, without optimising other system components is likely to result in sub-optimal operations (Lazare, 2013).

v. Mining cycle duration

Rupprecht (2018) indicated in the LoCM phase 1 closeout report that some operations are working beyond their 8h20min shift cycle (i.e. the 45-hour work week, 8h20min per day, that is set by the BCEA, 1997). Results from a time-motion study done at a platinum mine, as shown in Table 5, highlights an average duration of more than 8h20min from 12 shifts for different stopes. Figure 12 shows the number of minutes each activity takes in the mining cycle.

Table 5: Estimated average of 12 shifts in different stopes (Rupprecht, 2018)

Legal hours	Stope A	Stope B	Stope C	Stope D	Stope E
08:20:00/shift	10:36:52	08:39:38	10:55:55	13:01:27	09:33:15
45:00:00/week	52:07:00	43:30:00	54:45:00	65:12:00	47:50:00

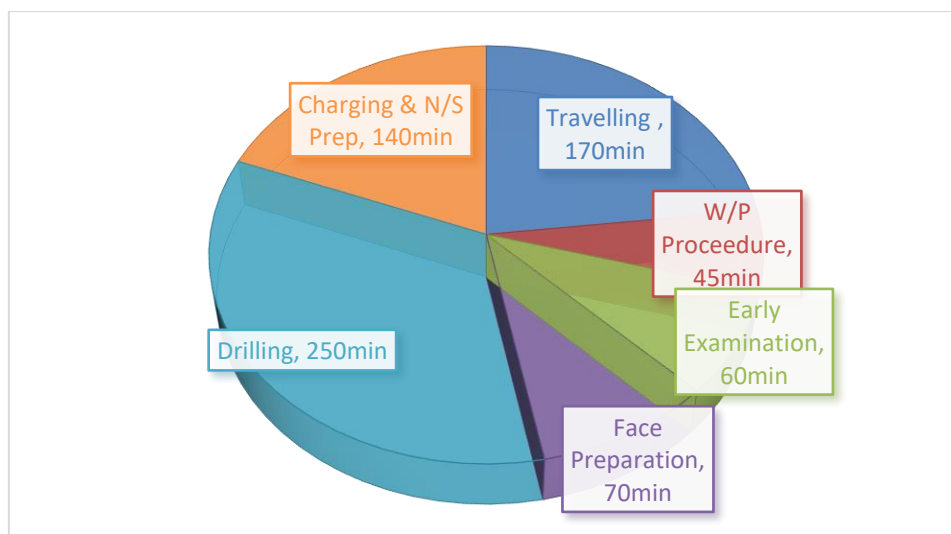


Figure 12: Duration of mining cycle activities in a South African gold operation (adapted from Rupprecht, 2018)

Underground work time motion studies done at a gold mine also indicated that the shift length extends beyond 8h20min. Figure 13 and Figure 14 show the different shift lengths in different levels, for the cleaning crew as well as the drill and support crew. Figure 13 shows that more than 60% of the shifts did not finish in time, and Figure 14 shows that none of the shifts finished in time (Lazare, 2013).

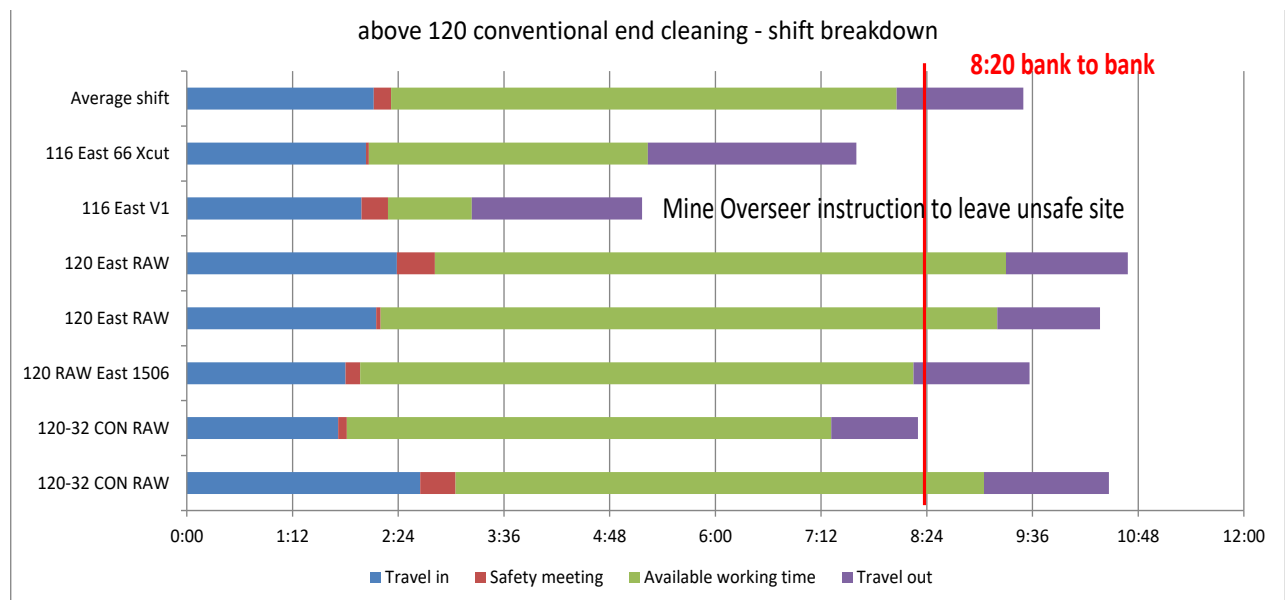


Figure 13: Cleaning crew shift length (Lazare, 2013)

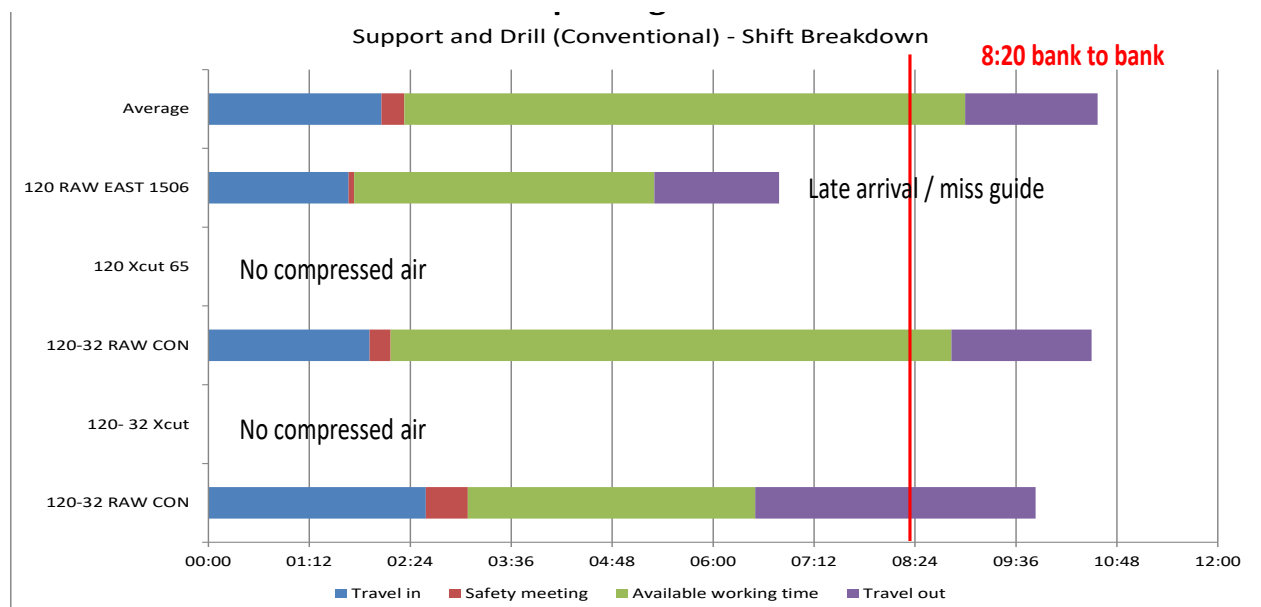


Figure 14: Support and drill crew shift length (Lazare, 2013)

The results clearly indicate that with the current shift length of 8h20min, it is impossible to complete most of the mining tasks in a single shift. In order to meet production targets, extended shift times must be considered.

3.5. Conclusion

Various factors to be considered in the redesign of shift cycles have been discussed. Shift schedules must be tailored in order to optimise productivity, OHS performance and to improve the well-being of employees. Involvement of employees, unions and management in the design of new shift cycles is highly beneficial in producing win-win outcomes. Longer shifts with longer time off work will give employees more time to rest and attend to their personal errands, potentially resulting in less fatigue, reduced absenteeism and increased productivity. Adequate supervision must also be availed to all shifts to ensure that the productivity and OHS targets are met, and to keep the workforce motivated. Controlled work schedules give the employees chance to train or study and upgrade their skills. Demanding schedules can be stressful, therefore good morale and a sense of team spirit is essential to assist the workforce to cope with the challenges.

In order to improve productivity, the South African mining industry must continually explore innovative mining practices such as technology introduction and changing shift cycles. The available face time in most underground narrow reef hard rock mines has been significantly reduced due to factors such as increased travelling distances to the working faces and increased OHS requirements. The current 8h20min shift length is no longer adequate to meet production and OHS targets, hence the requirement to introduce longer shifts and continuous operations. This will ensure optimum utilisation of assets, resulting in improved productivity. In choosing different shift rosters, legislative requirements and the impact of the shift cycle arrangements on OHS must be taken into account. It is imperative to understand that optimising asset utilisation with a focus on shift cycle changes is site specific, thus before deciding on any changes mines need to understand their operational needs.

In order to come up with optimum operations, a system thinking approach addressing all other systems elements such as the following is important:

- The impact of the shift cycle arrangements on OHS performance, mainly looking at factors such as fatigue;
- Consideration of other factors such as absenteeism, supervision, education and training, and social support and culture; and
- Investigation of the impact of the proposed changes on the existing mine infrastructure capacity, maintenance practices and capability, management and supervisor capability, as well as other mine support related services.

4. Data collection and analysis

4.1. Introduction

This report details findings from site visits conducted to collect data relating to shift cycles and productivity in the South African mining industry (SAMI). Data were collected from managers at two mine sites with the use of questionnaires, interviews, and requests for related data. The rationale and methods employed for this research are detailed in the previous project report. The results discussed in this report relate to numerous aspects associated with shift cycles at the participating mines, including productivity, and worker health, safety and wellness. Additionally, fatigue and accident risks associated with various shifts in use in the SAMI were calculated, and the results are provided. The results from this study, in addition to findings from a review of relevant literature, were used to inform a framework to optimise shift cycles in the SAMI, to maximise asset utilisation and occupational health and safety (OHS) performance.

4.2. Overview

Data were collected from two mine sites for this project. These mines included a mechanised platinum mine and a mechanised gold mine in South Africa. Data collection took place at the platinum mine (Mine 1) in April 2019 and at the gold mine (Mine 2) in August 2019. The methods employed in the research are detailed in the Milestone 4 report (*Data collection plan*) for this project. The findings of these case studies were used to inform the draft framework for optimising shift cycles in the SAMI, which comprises the next project milestone.

4.3. Mine 1

4.3.1. Mine description

The first case study was conducted at a platinum mine located in the eastern limb of the Bushveld Complex in Mpumalanga, South Africa. The mine operated underground, using low profile mechanised board and pillar mining, and was mined at depths of between 50 m and 850 m. Two decline shafts were operational. Two blasts per day were planned, and the re-entry period was approximately 1 hour. The mine used continuous operations (CONOPs). In 2018, the operations employed 2 397 enrolled employees and 784 contractors. At the time of the study, 22% of the workforce were female. Approximately 47% of the workforce were employed in mining, and 30% in engineering.

4.3.2. Shift cycles

The mine operated continuously for 24 hours a day, and seven days per week. Operations continued throughout the year, except for on certain public holidays. Two 10-hour production shifts operated each day, using a 5 day shifts, 5 night shifts, and 5 days off (5D 5N 5O) roster. The clock-in and clock-out times for the day shifts were 07h45 and 16h30, respectively, and were 20h45 and 05h30 for the night shifts, respectively. Discrepancies in official shift times were noted between different documentation at the mine. On the blasting schedule the stated shift times were from 07h00 to 17h30 and 19h00 to 05h30. The Human Resources scheduled

shift cycle times are shown in Table 6. Other shift cycles that were used at the mine were 4x4x4x4 or 4D 4O 4N 4O shifts (e.g. for essential services and at the plant), and straight shifts. The straight shifts operated from Monday to Friday, and only during the day.

Table 6: Shift cycles employed at a mechanised platinum mine

Shift cycle*	Shift length	Day shift		Night shift	
		Shift start	Shift end	Shift start	Shift end
CONOPs (5D 5N 5O)	10 hours	07h00	17h00	20h00	06h00
4x4x4x4 (4D 4O 4N 4O)	12 hours	07h00	19h00	19h00	07h00
Straight (5D 2O)	8 hours 40 minutes	07h00	15h40	N/A	N/A

*'D' refers to day shifts, 'N' refers to night shifts, and 'O' refers to days off

The total number of production days at the operations were approximately 341 days per year. Approximately 56 shifts were planned per month, with two days per month having been deducted for services. For maintenance purposes, each level was serviced every two weeks, during which the level stopped work for the shift. No service shifts took place during the night shifts or on weekends.

Employees worked on approximately 22 days per month. Employees on CONOPs worked an average of 243 shifts (2 430 hours) per year. Those working 4x4x4x4 worked an average of 183 shifts (2 196 hours) per year. Those who worked straight shifts worked an average of 261 shifts (2 262 hours) per year. These hours included expected shifts on public holidays. An agreement about the working arrangements was in place between the mine and labour unions. This agreement included 'working in' arrangements over selected public holidays, to allow for a break over the Christmas to New Years' period.

The engagement process for changes in shift cycles involved consultation with unions. A change had taken place regarding the shift cycles a few years previously. This change involved switching the day and the night shifts, so that the first shifts in the CONOPs cycle were day shifts. The previous shift cycle, in which the cycle started with night shifts, was a noted problem. Shifts are supposed to rotate in a forward, rather than a backward direction, to allow for better recovery between shifts. Communication, accountability and supervision availability between day and night shifts had also been concerns.

4.3.3. Overtime

Overtime work contributes to the total number of hours worked by each individual. The average number of overtime hours worked at the mine per month over the previous eight months was 11 796 hours. This value was 65 049 hours in the engineering department, and 22 048 hours in mining. The estimated average amount of overtime worked per month per person in the workforce was 2.4 hours in mining, and 11 hours in engineering. The mine was trying to limit overtime worked, in order to reduce overtime costs and reduce fatigue in the workforce. As some of the workforce from the engineering department worked on weekdays, overtime was especially prevalent over weekends. A potential strategy to avoid this overtime was to align the

schedules to the CONOPs cycle. Systems were in place to avoid employees working too many hours (e.g. more than 40 hours overtime per month).

4.3.4. Production

The number of tonnes produced for the two decline shafts was 172 000 t and 106 500 t per month, respectively. The amount produced per shift hour was calculated as 245.47 tonnes. The reported amount produced was 2 212.5 m² per half level, per crew (three mining teams). The target per crew was 300 m or 3 000 m². The team size for each shift (i.e. day, night, or off shift) was 15 people. Table 7 shows the planned breakdown of occupations in each team for 2019. There were 13 and 7 crews at the two declines, respectively.

Table 7: Planned team composition

Occupation	Number
Shift boss	1
Miner	1
Crew Captain / Team Leader	1
Drill Rig Operator	2
Roof Bolter Operator	2
LHD Operator	2
Emulsion Unit Operator / Assistant	2
UV Operator	1
PTV Assistant	4
Total	15

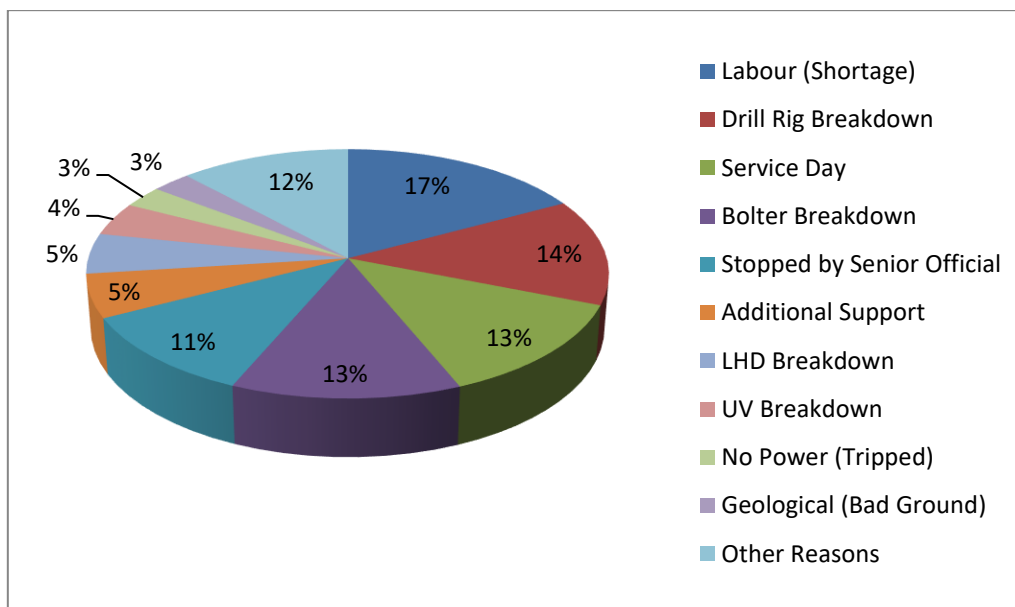


Figure 15: Top ten causes of lost blasts at a mechanised platinum operation

Blasting was planned twice per day (at 06h00 and at 18h00), and a centralised blasting system was used for both shafts. Gas levels were checked following the blasts to ensure that it was safe for the workers to enter. Reports of the total rate of lost blasts were analysed for the year to date. The overall rate of lost blasts was 20% (22.1% and 16.6% for each decline, respectively).

The top ten causes of lost blasts are shown in Figure 15. Labour shortages, breakdowns, and service days were among these causes. The 'other' causes of lost blasts, referred to in the diagram, included misfires, accidents, Section 54s, service problems, and panel flooding.

4.3.5. Face time, travelling times and ancillary activities

The CONOPs employees worked 10-hour shifts. Of this time, approximately 7 hours were spent at the work face. The average bank-to-bank time, including travelling time, was 8 hours per crew. The average travelling time to get to the face was approximately 30 to 40 minutes. The longest travelling distances were approximately 2.5 km, which could increase the travelling times up to 2 hours. The mine had decline shafts, and chairlifts were used to get to respective levels in the mine. The drill rigs and load haul dumpers (LHDs) operated for approximately 5 hours per day. The drilling time per face was approximately 2.5 hours per face, so around 2.5 panels could be completed per shift. Two spare panels were available to allow for redundancy. Drilling, supporting and cleaning could continue for the whole shift, as work could continue at another panel once one was completed.

An example of the typical daily routine, for the day shift, was reported as follows:

- Shift arrives at work at 07h00;
- Daily safety meetings from 07h15 to 08h00;
- Shift proceeds underground from 08h00 to 08h30;
- Waiting place meeting with respective crews;
- Early entry examination;
- Bolter – installation of bolts;
- Drill rig – normal drilling activity;
- LHD – cleaning of boards;
- Effective production from 10h00 till 16h00;
- Transport from 17h30; and
- Blasting at 18h00 (or between 17:30 and 18h30).

An analysis of the number of hours spent underground by mining crews for the previous seven days was conducted. The average, minimum, and maximum, number of underground hours for twelve crews at the first decline and seven crews at the second decline are shown in Table 8. The average number of underground hours worked ranged from 6 hours and 35 minutes to 8 hours and 23 minutes. In general, the night shift underground hours were longer than the day shift hours.

Table 8: Average underground hours for mining crews over seven days

	Decline 1		Decline 2	
	Day shift	Night shift	Day shift	Night shift
Minimum	3h 40m	7h 06m	3h 32m	4h 50m
Maximum	8h 49m	9h 24m	8h 00m	9h 33m
Average	7h 26m	8h 23m	6h 35m	7h 45m
Standard deviation	1h 09m	0h 34m	1h 02m	0h 58m

Results of face time studies conducted at the mine in 2011 were assessed. It was noted that, at the time, the stated shift durations from Human Resources figures (9 hours) differed from the chairlift times (10 hours). Base cases for each of the decline shafts were assessed, and the average face times were 7.66 hours and 7.35 hours, respectively. An example of a shift breakdown, as taken from the face time study documentation, is illustrated in Figure 16.



Figure 16: Face time study results at a mechanised platinum mine

The face time study findings included an assessment of the face times of the levels with the longest horizontal and vertical travel distances (Table 9). Collar-to-collar and face times appeared longer during the night shifts. The differences between the collar-to-collar times and face times in the declines were calculated to range from 49 to 98 minutes. In these cases, the walk to the waiting places ranged from four to 21 minutes, and the walk back to the chairlifts ranged from 17 to 29 minutes. Ancillary activities that workers conducted upon arriving at the mine, included:

- Collection of lamps and gas detection instruments;
- Queuing for chairlifts;
- Travelling on chairlifts;
- Walking to waiting place;
- Safety meetings;
- Travelling to face;
- Walking to chairlift; and
- Travelling to surface.

Table 9: Face time assessments at a mechanised platinum mine

	Longest horizontal travel		Longest vertical travel	
	Day shift	Night shift	Day shift	Night shift
Face time	6h 14m	8h 01m	6h 47m	7h 46m
Collar-to-collar	7h 52m	8h 50m	8h 06m	8h 56m
Difference between collar-to-collar and face times	98 min	49 min	79 min	70 min

It was reported that, at the time, mass safety meetings of around 20 to 25 minutes were held during re-entry periods, and zoning options for these were assessed. Options to increase the rate and capacity of the chairlifts were also assessed, to decrease the travel times into and out of the mine. The negative effects of late blasts were also mentioned.

4.3.6. Working conditions

The mine was classified as a hot mine, as the temperatures were above 27.5°C. However, the work was not considered to be labour intensive, which helped to minimise the strain on the workers, and mitigate fatigue-related risks associated with long shifts and work in hot environments.

Breaks during work, and the provision of sustenance, can help to mitigate fatigue associated with long shifts. Lunch breaks were not officially scheduled, but were generally 20 minutes long, and agreed upon with the supervisor. However, compulsory stopping times during the work shifts were noted, in which the workers got out of their vehicles (e.g. five minute breaks at 11, 1, and 3 o' clock in the morning or evening). The mine provided mid-shift feeding, in which they provided *FUTURELIFE* sachets to the workers.

4.3.7. Commuting times

The time taken for workers to travel to and from the mine affects the amount of time available to sleep and rest outside of shift times. The living conditions of mine workers can also affect their sleep, health and fatigue. There were no hostels at the mine, but a housing scheme was available in the neighbouring town. The majority of the workforce were local, but around 180 were migrants.

Mine buses were available to transport workers to and from the surrounding communities. The travelling distances ranged from 4 km up to 70 km and the buses were scheduled according to the shifts worked at the mine. The earliest morning pick-up times of the transport were around 05h15, to allow for arrival at the mine at 06h30. The earliest evening pick-up times were 18h20, to arrive at the mine by 19h30 (for the CONOPs shift). The earliest departure times following day shifts were 16h00 (straight shift), and around 17h30 for the shift workers. The earliest departure times following night shifts were around 06h30.

As such, it is estimated that an employee with a commuting time of 1 hour between home and work, who works 10-hour shifts, should have 11 hours available for personal activities and sleep during each workday. This time allows for the additional half hour between transport

arrival/departure and working times, but excludes the time taken from leaving the place of residence to arrive at transport pick-up points and wait for the transport to arrive.

4.3.8. Health, safety and wellness

Shift work is associated with health and safety risks, including those relating to fatigue. The fatality frequency rate at the time of the assessment was 0.00 and the lost-time injury frequency rate was 0.5 (per 200 000 shifts worked). The average turnover rate at the mine was 0.5%, and a large portion of the workforce had been at the mine since its inception. Most of the workforce had a matric (Grade 12) education, and compensation of the workers was considered to be good. Socioeconomic conditions are associated with health and wellbeing.

Shift work is further associated with absenteeism. The absenteeism rate of the mine was considered to be relatively low. The average unavailability rates for the two declines for the previous three months are shown in Table 10. The average rate of sick leave ranged from 3.5% to 4.5%, and the average annual and other leave ranged from 7% to 13.5%. The threshold for sick leave was 4%, and was 8.3% for annual and other leave. Community unrest was a reported cause of absenteeism. Absenteeism without permission (AWOP) was another form of unavailability. Unavailability peaked at the beginning of January, and appeared to be higher at the end of each month.

Table 10: Average unavailability at a mechanised platinum mine

Month	Decline 1			Decline 2		
	Jan-19	Feb-19	Mar-19	Jan-19	Feb-19	Mar-19
Sick leave	4.0%	4.5%	4.5%	3.5%	3.5%	3.8%
Annual and other leave	13.5%	7.1%	7.2%	12.4%	7.0%	7.2%
Total leave	17.5%	11.6%	11.7%	15.9%	10.5%	11.0%

In general, the implementation of CONOPs at this platinum mine was considered successful. Factors that were considered in relation to the shift cycles included face times, blasting times, overtime worked, working conditions, travel and ancillary activities, maintenance, and support. Meanwhile, fatigue management, the effect of commuting times, and the effects of shift work on health, safety and wellness, were also considered.

4.4. Mine 2

4.4.1. Mine description

The second case study site was a fully mechanised gold mine located in Westonaria in Gauteng, South Africa. The mine operated underground, at depths of 3 000 m, and utilised a single shaft. The mine operated using CONOPs, or 'full calendar operations' (FULCO). The mine planned to blast twice per day although, at the time, only one blast took place per day. The re-entry period was approximately 1 hour. At the time of the study, the mine employed 2 375 permanent staff and 1 826 contract workers, and 22% of the workforce were women. Approximately 77% of the employees worked underground and 23% on surface.

4.4.2. Shift cycles

The mine operated on seven days per week, and production took place throughout the year. Two main shift cycles were in place. The mining production teams, and some engineering personnel, operated 4x3 (or 4x4) shifts (4D 4O 4N 4O) that were 11.5 hours long. A maintenance shift was incorporated into this roster, such that three production shifts and one maintenance shift took place in the cycle. The reported clock-in and clock-out times for the day shift were 05h45 and 17h35, and 17h40 and 05h35 for the night shifts, respectively. However, as these times do not precisely encompass 11.5-hour shifts, there might be a misunderstanding of the timing shift when capturing the information. Additionally, it is not clear when employees were required to arrive at work versus when they clocked-in at the shaft.

Further engineering or maintenance personnel worked 9-hour 6-1, 5-2 shifts. This shift cycle is referred to as the 11-shift fortnight, and the maintenance team worked on rotation for six days on one week (Monday to Saturday) and on five days (Monday to Friday) for the following week. It appeared that this working arrangement only incorporated day shifts at this mine. Illustrations of the FULCO and 11-shift fortnight shift schedules are shown in Figures 17 and 18 (where N = night shift; D = Day shift; O = off).

JANUARY 2019	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
CYCLE A	O	O	D	D	D	D	O	O	O	O	N	N	N	N	O	O	O	O
CYCLE B	N	N	O	O	O	O	D	D	D	D	O	O	O	O	N	N	N	N
CYCLE C	D	D	O	O	O	O	N	N	N	N	O	O	O	O	D	D	D	D
CYCLE D	O	O	N	N	N	N	O	O	O	O	D	D	D	D	O	O	O	O

Figure 17: FULCO shift schedule at a mechanised gold mine

JANUARY 2019	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Cycle B	D	D	D	D	D	O	D	D	D	D	D	O	O	D	D	D	D	D	D	O
Cycle A	D	D	D	D	O	O	D	D	D	D	D	D	O	D	D	D	D	D	O	O

Figure 18: 11-shift fortnight schedule at a mechanised gold mine

Production could take place on 351 days per year at the mine. An agreement was negotiated for workers to work for six of the 12 national public holidays, and be off for the other six public holidays (Workers' Day, Good Friday, Family Day, Christmas Day, Day of Goodwill, and New Year's Day), and over the Christmas break (between Christmas and New Year). Additionally, it was noted that an increase in the number of non-production days could assist with maintenance at the mine.

The mining employees worked approximately 15 days per month, and 180 shifts per year (including training and leave). This value worked out to 2 070 hours per year, and an average of 40 hours per week. The total number of production shifts per month was 60 (30 days x 2 shifts), and the total calculated number of shift hours per month 690 hours. Table 11 shows the estimated average number of days worked for the two shift types for the previous year.

Table 11: Estimated number of employee days worked

	4x4 cycle	6-1, 5-2 cycle
Number of work days, including:	180	277
Annual Leave	21	21
Easter	2	2
Christmas	6	6
Sick	9	9
Training	24	24
Absent	5	5
Other	6	6
Number of days off	185	81
Total days	365	365
Total number of days at work	107	204

4.4.3. Change to shift cycles

Changes to the shift systems had been implemented at the mine at the start of the previous year. The changes were made to extend the shifts, and aimed to improve production and productivity, as the previous shift structure was not considered to be suitable for the mine. The previous shifts followed a 7-2, 7-5 (9.5 hour) system, and overtime was worked beyond these hours. Before the current 4x3 cycle was implemented, a change to 4x4 shifts was made; however, problems with maintenance were reported, so a maintenance shift was provided for in the cycle. Remuneration was provided for shift work, including FULCO and straight allowances of up to a third of the workers' salaries.

Consultation and negotiation with took place before shift changes were implemented, and employee representatives (unions) were part of the process of changing the shift systems. Consultative forums took place to jointly decide on a change management plan to implement the changes. A Continuous Operations Agreement and Memorandum of Understanding (and their Addendums) between the mine and the two unions had been drafted and signed. Changes to shift configurations also aimed to reduce the retrenchments that were underway at the mine, while the agreements also included sections about excess labour and voluntary separation.

The reported advantages of the current shift cycle included longer production shifts and better maintenance. This resulted in increased production outputs, improved safety and better fleet maintenance. However, the cited disadvantages were higher absenteeism and fatigue, along with the time taken for people to get to work.

4.4.4. Overtime

The use of overtime at the mine was limited, and was constrained by the shift length. However, overtime did take place on 'off' days, when reasonably required. Overtime was controlled, and approvals for requests were required from Head of Departments or designated Senior Officials. Exemptions were obtained, so that overtime was limited to 40 hours per month (or 10 hours per week). If more than 40 hours of overtime had been worked, then the system at the mine blocked entry. Exemptions were also obtained from the Department of Mineral Resources (DMR) for Sunday work.

The total number of hours overtime worked in the previous month was 3 122 hours, of which 1 762 hours were for engineering department, and 487 hours for mining. The average amount of overtime, out of those who took overtime in the previous month, was 25 hours. This average was 23 hours in engineering, and 20 hours in mining.

4.4.5. Production

The average number of tonnes produced at the mine per month for the past year was 90 000 tonnes. This amount was lower than the previous years' average of 110 417 tonnes, because of a 42 day strike that had taken place. The average amount produced per crew was 60 m per drill rig per month, and the average crew consisted of 16 people. The mine aimed to attain a production rate of 90 m per month.

Contingency plans were in place in terms of labour, equipment and power at the mine. Additional labour was planned for certain occupations in production. The planned contingency was around 15% per section, and an extra roving crew was available. A solar plant was being constructed to generate power for the mine. An excess of equipment was reported, and the fleet was being reduced, while a planned maintenance programme was also being implemented. Constraints that were noted were a shortage of operator skills, the maintenance of equipment, and challenges with technology.

A summary of problems booked at the mine for the year to date is shown in Figure 19. The majority of the reported problems related to support. Other problems included those relating to services and breakdowns.

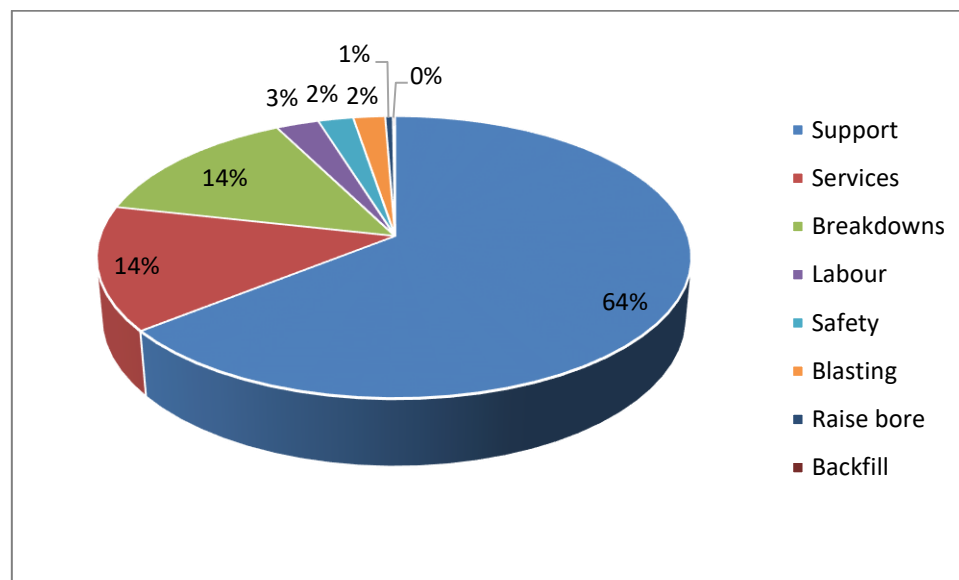


Figure 19: Problems booked at a mechanised gold mine

The 4x3 shift schedule allowed for a maintenance shift. Meanwhile, maintenance personnel also worked 6-1, 5-2 shifts. Support services were considered to be adequate for each shift, as they also worked continuous shifts. In terms of supervision, it was evident that Shift Supervisors worked on each shift, although the Mine Overseers primarily only worked during the day.

4.4.6. Face time, travelling times and ancillary activities

The available face time was considered to be sufficient for mining cycle tasks to be completed. Face time was regulated by supervisors and systems in place at the mine. The crews were allowed to leave earlier if certain activities were completed. During the 11.5 hour shift, time spent at the face was noted to range from 8 to 11.5 hours, and incorporated at least two of the following activities:

- Drilling (4.2 hours);
- Charging and blasting (2.5 hours);
- Support (5.2 hours); and
- Loading (3.4 hours).

The time taken for workers to travel from the lamp room to the work place was approximately 1 hour. The horizontal travelling distances of the workplaces were up to 2 km. The workers walked and/or used trains to travel underground. The re-entry period of 1 hour was relatively short because of the long travelling times, and as the working place was not confined.

4.4.7. Working conditions

The work environment could contribute to health and safety risks associated with long shifts. The average wet bulb temperature in the workplaces was 27.5°C.

4.4.8. Commuting times

Most of the workers were reported to live within a 15 km radius of the mine. Workers used a range of transport modes to commute, including public transport, private vehicles, and mine buses (for those living in the mine hostel). The working hours were adjusted to accommodate for public transport availability. It was perceived that workers could spend approximately 10 hours at home after accounting for working hours and commuting times.

It was reported that some of the workers lived in informal housing (shacks), and the poor living conditions associated with this housing could contribute to fatigue. Around 600 workers resided in the mine hostel, and the mine also had a housing policy, which enabled workers the opportunity to buy houses.

4.4.9. Health, safety and wellness

Fatigue was considered a challenge because of the long shifts worked. The high temperatures in the mine, caused by the depth of the mine and the operation of machinery, could also contribute to fatigue. Measures were in place to manage fatigue at the mine, including a fatigue management programme, training provided to workers, a fatigue management process followed by supervisors, and a wellness programme. Workers were provided with meal breaks (~30 minutes) and meals ('mid-shift feeding') during work.

The mine had in place a COP for risk-based fatigue management, in accordance with legal requirements. The COP addressed potential causes of fatigue, including medical, lifestyle,

workplace, and psychological factors. Sleep was an important factor, along with the influence of circadian rhythms. The development of a fatigue management plan was referred to, which incorporated aspects such as management commitment and stakeholder buy-in, fatigue risk management, and fatigue risk management tools.

The absenteeism rate at the mine for all causes was 15.99% for the year to date, and was considered to be reasonable. This value compared to a rate of 15.02% for the previous year. The absenteeism value, comprised approximately 43% annual leave, 24% training, 14% sick leave, 3% 'absent', and 16% 'Other'. Absenteeism was reported to be higher over pay weekends, during school holidays, and at the start of winter (because of illness). The fatality frequency rate was 0.00 and the lost-time injury rate was 1.20 for 2019 at the time of the data collation. These values were lower than the rates for the previous year (0.05 and 0.98, respectively).

In summary, the findings from assessment of the shift cycles in use at this mechanised gold mine, indicated benefits for the use of the FULCO shifts that had been implemented. The shift length had been extended to 11.5 hours, and a maintenance shift was incorporated into the shift cycle. The advantages of this roster included better production and maintenance, but disadvantages included higher absenteeism and fatigue. Consultation and negotiation were important to ensure the successful implementation of changes in the shift cycles. Fatigue management at the mine considered numerous aspects, including the work environment, commuting, living conditions, and nutrition.

4.5. Fatigue and risk analysis

This section details findings from a fatigue and accident risk analysis conducted on a number of different shift cycles in the mining industry. Innumerable potential shifts could be implemented in the SAMI. The shift rosters analysed for the purposes of this report are shown in Table 12, and are examples of shift rosters that have been implemented in the SAMI. Illustrations of the scheduling of the three included CONOPs shift cycles (2D 2N 4O, 4D, 4O, 4N 4O, and 5D, 5N, 5O), are shown in Figures 20 to 22.

Table 12: Shift rosters analysed for fatigue and accident risk
(D = Day shift, N = Night shift, O = Day off)

Shift type	Shift cycle	Shift length	Day shift		Night shift	
			Shift start	Shift end	Shift start	Shift end
CONOPs	2D 2N 4O	12 hours	07h00	19h00	19h00	07h00
	4D 4O 4N 4O	12 hours	07h00	19h00	19h00	07h00
	4D 4O 4N 4O	11.5 hours	06h00	17h30	18h00	05h30
	5D 5N 5O	10 hours	07h00	15h00	20h00	06h00
Day shift only	5D 2O	8h 40m	07h00	15h40	-	-
	5D 2O 6D 1O	9 hours (Sat.: 5 hours)	07h00	16h00 (Sat.: 12h00)	-	-

	M	T	W	T	F	S	S	M
	1	2	3	4	5	6	7	8
Team A	D	D	N	N	O	O	O	O
Team B	O	O	D	D	N	N	O	O
Team C	O	O	O	O	D	D	N	N
Team D	N	N	O	O	O	O	D	D

Figure 20: Example of a 12-hour shift roster with a 2D 2N 4O cycle

	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Team A	D	D	D	D	O	O	O	O	N	N	N	N	O	O	O	O
Team B	O	O	O	O	D	D	D	D	O	O	O	O	N	N	N	N
Team C	N	N	N	N	O	O	O	O	D	D	D	D	O	O	O	O
Team D	O	O	O	O	N	N	N	N	O	O	O	O	D	D	D	D

Figure 21: Example of a 12-hour shift roster with a 4D 4O 4N 4O cycle

	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Team A	D	D	D	D	D	N	N	N	N	N	O	O	O	O	O
Team B	N	N	N	N	N	O	O	O	O	O	D	D	D	D	D
Team C	O	O	O	O	O	D	D	D	D	D	N	N	N	N	N

Figure 22: Example of a 10-hour shift roster with a 5D 5N 5O cycle

The Health and Safety Executive (HSE) fatigue and risk index was used for this analysis (<http://www.hse.gov.uk/research/rrhtm/rr446.htm>). The fatigue and risk index was designed to compare different shift schedules, but can also be used to identify a particular shift within a schedule that could be a concern. Fatigue and accident risk scores are provided for each shift within a schedule. The fatigue and risk indices are similar in many respects, but differences include time of day effects, such as that accident risk tends to occur close to midnight, while fatigue tends to peak in the early morning.

The fatigue score ranges from zero to 100, and indicates the percentage chance of experiencing high levels of sleepiness. For example, a score of 50 represents at 50% chance that workers would experience high levels of sleepiness, such that they might struggle to stay awake on that shift. There are currently no threshold fatigue scores.

The accident risk index refers to the relative risk of the occurrence of an accident or incident. A 1.0 risk score indicates a baseline value for a typical 2D 2N 4O schedule with 12-hour shifts, in the rail sector. A risk score of two represents a doubled risk.

The calculator allows the default settings for the shifts to be adjusted according to commuting times, job types, and job breaks components. For the current analysis, the default settings for the calculations of these shift cycles were adjusted as follows:

- **Workload:** Moderately demanding, little spare capacity;
- **Continuous attention:** Most of the time;
- **Rest breaks:** 30 minutes every 5.5 hours, 5 minutes every 2 hours; and

- **Commuting time of employees to or from work: 1 hour.**

These factors have significant impacts on the fatigue and accident risk scores. For example, the risk scores would be higher if the workload and attention demands are higher. The rest breaks taken have a substantial impact on the fatigue and accident risk scores, as they provide an opportunity for rest and recovery during the shift. Longer commuting times of workers also increase the potential risk. Additionally, the start and end times of shifts have an impact of the risks associated with the shift rosters.

The results of the analyses of the shifts displayed in Table 12 are shown in Figures 21 to 28. Figure 23 illustrates four cycles of the 2D 2N 40 schedule over a course of 28 days. Figure 24 illustrates two cycles of the 4D 40 4N 40 schedule with 12-hour shifts. Meanwhile, Figure 25 illustrates the same schedule, but with 11.5-hour shifts, and earlier shift starting times. The fatigue and accident risk of the 5D 5N 50 roster is shown in Figure 26. The risks over four weeks associated with rosters that incorporate only day shifts, worked during the week only, or during the week and on alternate Saturdays, are shown in Figures 27 and 28, respectively.

It is evident that the risk scores, particularly for fatigue, are higher during night shifts than during day shifts. Additionally, the fatigue and accident risks increase with the number of consecutive shifts worked. Meanwhile, the days off provide an opportunity for recovery in between shifts worked. If fatigue and accident risk scores do not return to original values when the cycle is repeated, it indicates that workers do not have the opportunity to fully recover within the shift cycle. In the schedule in which Saturdays are worked fortnightly, higher fatigue scores were evident in the week following the six-day work week (Figure 28).

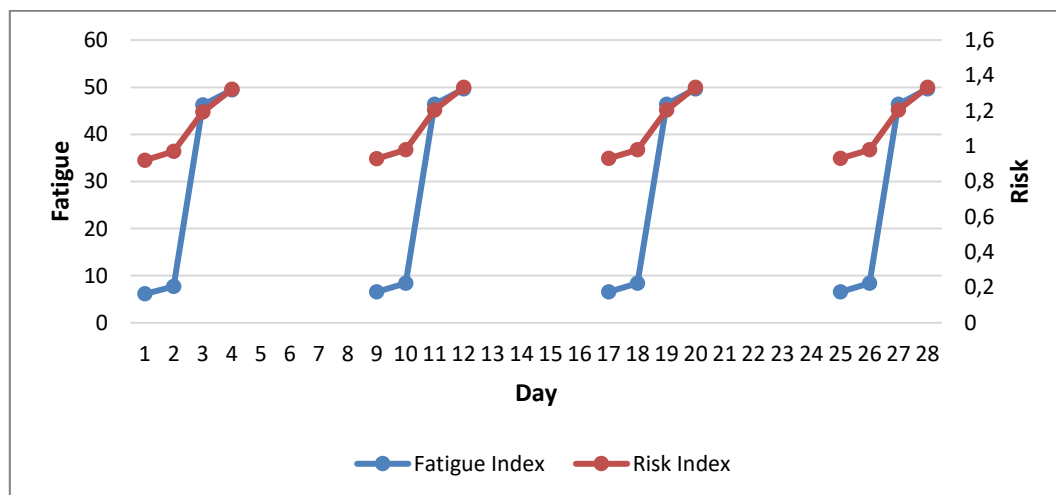


Figure 23: Fatigue and accident risk of 2D 2N 20 cycle with 12-hour shifts

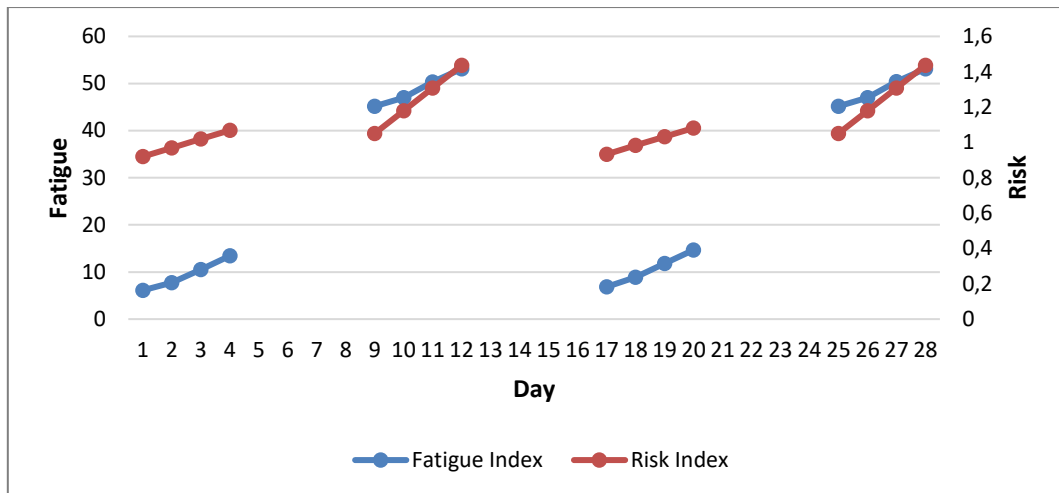


Figure 24: Fatigue and accident risk of a 4D 40 4N 40 cycle with 12-hour shifts

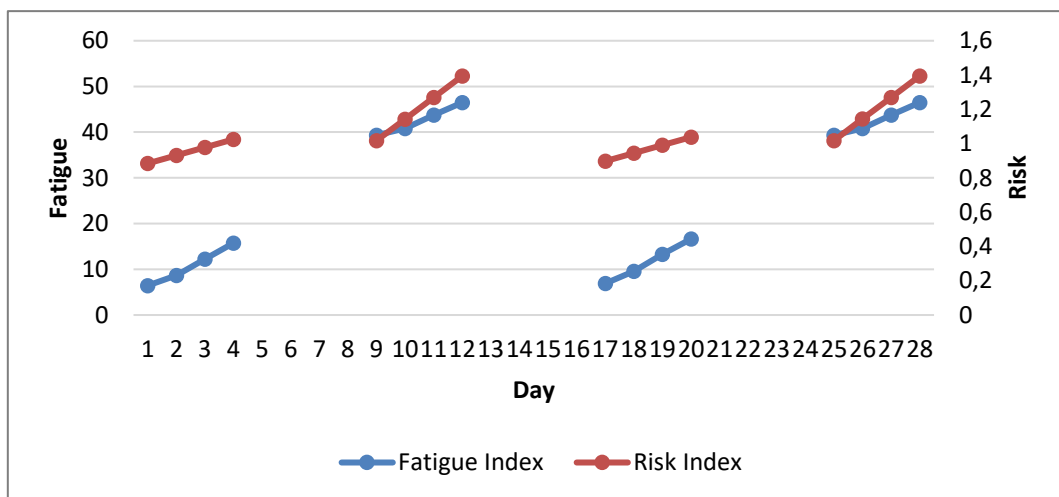


Figure 25: Fatigue and accident risk of a 4D 40 4N 40 cycle with 11.5-hour shifts

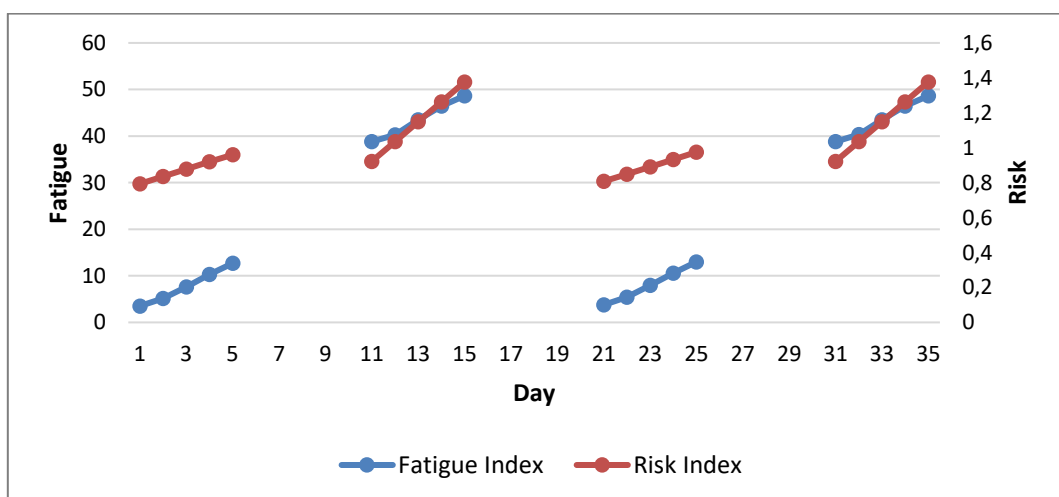


Figure 26: Fatigue and accident risk of a 5D 5N 50 cycle with 10-hour shifts

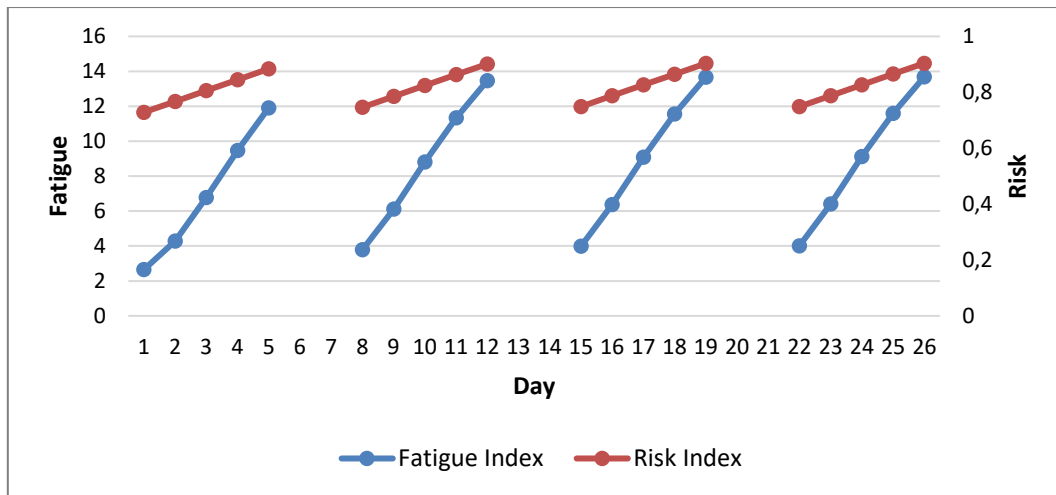


Figure 27: Fatigue and accident risk of a 5D 20 cycle with 8h 40m shifts

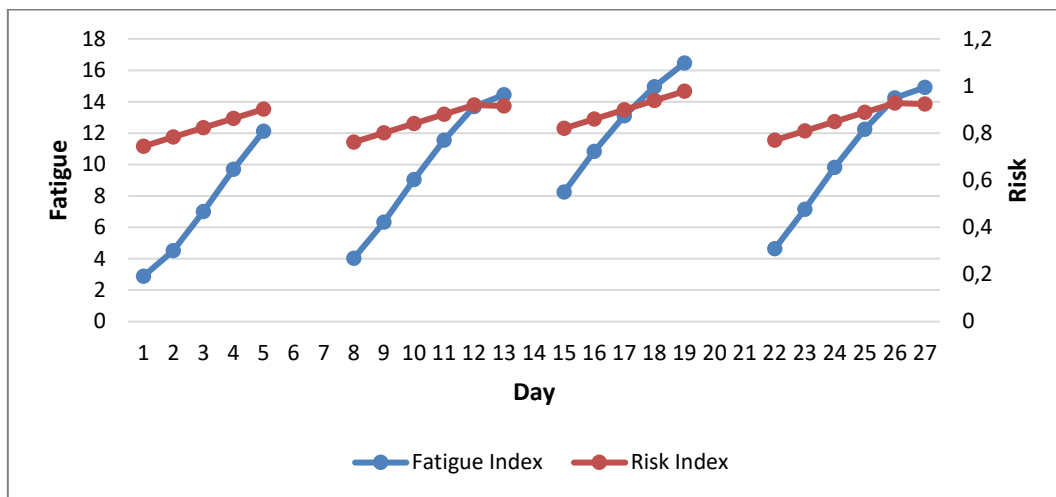


Figure 28: Fatigue and accident risk of a 5D 20 6D 10 cycle with 9-hour shifts

A comparison of the average, minimum and maximum fatigue and accident risk of the analysed shift rosters are shown in Table 13. Higher fatigue and accidents scores were evident for the rosters with longer shift lengths. Meanwhile, lowest risk scores were evident in the rosters that only incorporated day shifts.

Table 13: A comparison of the calculated fatigue and accident risk of the analysed shifts

Shift cycle	Shift length	Fatigue risk			Accident risk		
		Average	Minimum	Maximum	Average	Minimum	Maximum
2D 2N 4O	12 hours	27.7	6.1	49.7	1.110	0.920	1.332
4D 4O 4N 4O	12 hours	29.5	6.1	53.1	1.120	0.920	1.437
4D 4O 4N 4O	11.5 hours	26.9	6.5	46.5	1.080	0.884	1.395
5D 5N 5O	10 hours	25.8	3.5	48.6	1.020	0.793	1.377
5D 2O	8h 40m	8.4	2.7	13.7	0.820	0.729	0.904
5D 2O 6D 1O	9 hours	9.9	2.9	16.5	0.860	0.744	0.978

The findings from this analysis provide a comparison of the levels of fatigue and accident risk associated with different shifts, and when peak risk is expected within the roster. However, as noted on the developer's website, this tool should not be relied on as the primary means to

assess the risks. Additionally, various factors cannot be incorporated in to the index, including individual differences, social factors, and specific work-related factors. Shift scheduling and fatigue management needs to be adapted to the specific needs of each operation and workforce.

4.6. Discussion and conclusion

This report detailed findings of research relating to shift cycles, and specifically the use of CONOPs or FULCO, at two mining operations in South Africa. The study was conducted at a mechanised gold and a mechanised platinum mine. The implementation of CONOPs might differ, in some respects, to that at conventional mining operations. For example, differences in re-entry periods and working conditions could be evident. However, the basic principles relating to the use of CONOPs, such as the pros and cons of implementation, could be applied to different types of mining operations.

For both of the participating operations, two production shifts of between 10 and 11.5 hours took place daily. Blasting was planned to take place twice daily, and the re-entry period at both mines was approximately 1 hour. Discrepancies between different documentation were evident for official shift times and clock-in and clock-out times. Furthermore, the times of arrival and departure from the mine should be assessed, in relation to effective shift times.

Both of the mines operated throughout the year, except for on certain days, such as over Easter and the Christmas break. The total number of production days reported per mine was 341 and 351, respectively. Maintenance shifts were included in the rosters at the mines, and were planned approximately once or twice a month. Overtime was worked by the engineering teams more frequently than the production teams, as a result of the shift rosters worked. Alignment in shift rosters between these departments would help to reduce overtime and improve maintenance. Good communication and available supervision throughout all shifts was also noted to be beneficial. Additionally, the use of spare panels and extra work teams assisted with continued production. Furthermore, improved skills and applications of new technologies could assist to improve production within these shifts.

Ancillary activities conducted included travelling to and from work-faces, safety and waiting place meetings, and early entry examinations. Activities performed on surface prior to entering the workplace included the collection of cap lamps and gas detection instruments, and queuing for transport to get underground. Travelling times into and out of the mines was approximately 1 hour. The longer shift times that were implemented helped to increase face times and productivity at the mines, in relation to the total number of hours worked. Average face times ranged from six to eight hours per shift.

Fatigue and absenteeism are evident challenges relating to shift work. Shift rosters were analysed for fatigue and accident risk. It was evident that increased risk is associated with longer shifts, night shift work, an increased number of consecutive shifts worked, and a lack of breaks between and within shifts. The working conditions, such as the heat in underground environments, and work that requires high physical demands and continuous attention, can further exacerbate these risks. Additionally, individual differences, including those relating to women in mining, can have an effect on susceptibility to fatigue and OHS risks associated with

shift work. Rest breaks during work, and adequate nutrition, are important mechanisms to maintain alertness during work.

Commuting times and living conditions also have an effect on the workforce and OHS outcomes. Long commuting times reduce the time available for rest and recreation. It was estimated that employees working 10-hour and 11-hour shifts had approximately 11 hours and 10 hours, respectively, available for rest and recreation, when excluding commuting times. Additionally, poor living conditions can affect the quality and quantity of sleep obtained. Lifestyle and social factors also have a role to play.

The development of shift cycles and fatigue management plans should be unique to each operation. The whole system of mining needs to be considered in the application of changes to shift cycles. Related considerations include that of remuneration, supervision, maintenance, and logistics. The infrastructure and equipment or technologies at the mine further influence the appropriateness of certain shift roster options. The social and community impacts of shifts worked should also be assessed. Potential benefits of continuous operations, in addition to improved productivity and asset utilisation, include less retrenchments and increased jobs, as more workers will be required to enable the mines to operate for additional hours.

In conclusion, the use of CONOPs could help to improve productivity and sustainability of the SAMI. However, numerous factors need to be considered when assessing the most appropriate shift cycles for each operation. Continued monitoring and evaluation of shift cycles is similarly required when there are changes to work systems or processes. Furthermore, the successful implementation of changes to shift cycles will require consultation and negotiation between stakeholders. The following project milestone is a draft framework for the optimisation of shift cycles in the SAMI, and was based on a review of local and international literature, and the findings of this research.

5. Draft framework

5.1. Introduction

5.1.1. Purpose

The purpose of this framework is to provide guidance on how mines can optimise shift cycles, in order to maximise asset utilisation and occupational health and safety (OHS) performance. Optimal shift rostering systems should meet the following requirements:

- Optimise mine asset utilisation and productivity. Mine assets include ore reserves, plant, equipment and machinery;
- Optimise the utilisation of human resources (labour). The shift rosters must minimise additional labour-related costs, particularly those arising from overtime and idle time;
- Optimise OHS performance;
- Optimise the workforce's work-life balance and wellness;
- Comply with legal requirements and company standards; and
- Must not compromise safety standards or working conditions.

The framework was compiled using best practice information obtained from literature reviews, mining companies and engagements with mining industry subject matter experts. Stakeholders of the mining industry were given an opportunity to provide technical input into the draft framework at a workshop that was held at the Mandela Mining Precinct on 25 October 2019. Engagements with further stakeholders, including labour representatives, will be required prior to the finalisation of guidelines for the industry. The framework was developed with a focus on underground narrow-reef hard-rock gold and platinum group metals (PGM) mines, but could be useful for any mining operation.

5.1.2. Background

The productivity of most South African underground conventional gold and PGM mines is declining, operational costs are increasing, and profit margins are shrinking, while health, safety, social and environmental challenges are also present. Many of the deep-level underground mines in the country are aging and increasing in depth. As a result, mining activities are constantly progressing further from the shafts, requiring the workforce to spend a significant amount of the available shift time travelling to and from the workplace. The total available face time is further reduced by the time that employees spend fulfilling OHS obligations such as re-entry requirements, making safe procedures and continuous risk assessments. Previous research has indicated that current shift lengths of 8h20min may no longer be adequate to complete the required mining activities (Rupprecht, 2018).

In some instances, mining companies have attempted to improve productivity through the implementation of point solutions such as investing in additional resources (employees, materials, equipment, etc.). In the process, the mines made significant financial injections in productivity improvement initiatives while the effort only resulted in marginal productivity improvements. There has generally been a lack of a systems approach in dealing with the challenges faced by the mining industry. In line with the law of diminishing returns, the addition

of more of a single factor of production, while holding all others constant, will eventually result in decreasing returns. Improving the shift roster is a potentially cost-effective means of improving productivity and profitability of the business. Continuous operations, involving an increase in annual production days, and extended shift lengths, have been recommended to maximise asset utilisation, and hence sustainability, in the South African mining industry (SAMI) (Lazare, 2013). The ideal shift roster must support just-in-time (JIT) mine production i.e., it must ensure the availability of the right resources (equipment, material, employees, etc.), at the required mine face, at the right time and at the right cost.

5.1.3. Aim and objectives

The Longevity of Current Mines (LoCM) programme of the South African Mining Extraction Research, Development and Innovation (SAMERDI) strategy commissioned a project to assess shift cycle times in the SAMI. Research was recommended to investigate the possibility of using continuous mining to improve safety, productivity and revenue. The intention of this research was to contribute to the selection of optimal shift cycles for narrow reef mining environments. Another need that was identified was to understand the effects of travelling from home to the stope face, and back again, especially regarding its effects on fatigue.

The main outcome of the project was to draft a framework to optimise shift cycles in the SAMI. This framework focusses on aspects including productivity and fatigue. The optimal shift system for any operation will depend on a number of factors. Various considerations need to be made when implementing changes in shift systems or in optimising current shifts, and a number of these considerations are listed in the framework. This framework was designed to assist operations to determine the most suitable shift systems that can be implemented to enhance productivity and efficiency, while supporting the health, safety and quality of life of the workforce.

This project was aligned with work conducted by the Successful Application of Technology Centred Around People (SATCAP) programme, which focused on “Change processes and stakeholder engagement for shift cycles appropriate to modernisation”. Change management and stakeholder engagement processes are important to enable successful changes to shift cycles and, therefore, these matters should be considered in conjunction to this report.

5.2. Framework

5.2.1. Proposed framework for optimising shift cycles, to maximise asset utilisation and OHS performance, for underground narrow reef hard rock mines

The ideal shift rostering system for the mining sector must holistically consider and balance operational requirements, employee needs and OHS requirements (Figure 1). Any shift roster that does not balance these key requirements is likely to be ineffective. For example, a schedule focusing on meeting operational needs only (e.g., maximising productivity and profitability), without consideration of OHS and workforce needs, will result in poor OHS performance and lack of buy-in and support from the workforce. Sound knowledge of shift rostering systems and available shift roster options is also critical for an informed shift schedule selection and optimisation exercise. Developing and implementing a new shift schedule at an operational

mine, is a fundamental change that must be underpinned by a structured change management structure. Moreover, successful implementation of new shift cycles requires productivity and OHS targets to be met on all the shifts. This framework will highlight key shift roster design elements. A summary of the considerations that should be made is included in Appendix A.

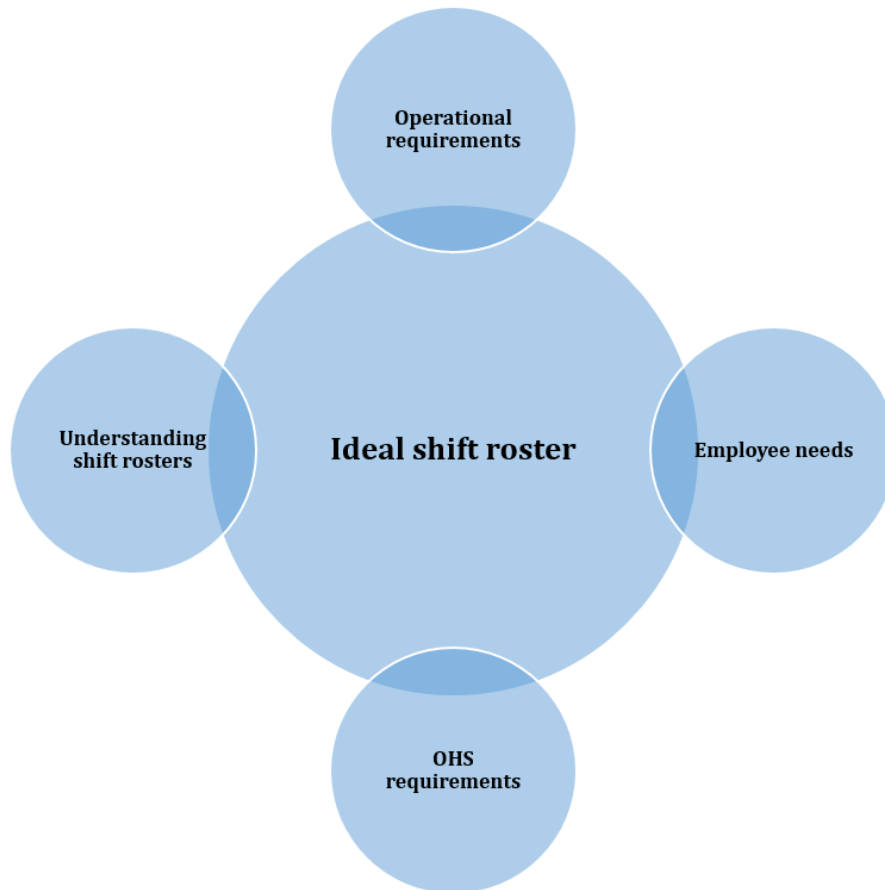


Figure 29: Key shift roster design elements

5.2.2. Shift cycles

Shift work refers to “an organisation of work where workers succeed each other at the same workplace while performing similar operations at different times of the day thus allowing longer hours of operation than feasible for a single worker” (South Africa, 2014, p36). Continuous shift work refers to operations that take place 24 hours per day, seven days per week, and throughout the year; semi-continuous shifts operate 24 hours per day, but with a break at the weekend; and discontinuous shift work refers to when operations take place for less than 24 hours per day, and there is at least one break in a day (e.g., ‘two-shift’ system) (South Africa, 1998). For the purpose of this framework, continuous operations (CONOPS) refer to operations that operate continuously for seven days per week, throughout the year.

Numerous shift cycles are used in industry, and typically involve three 8-hour shifts or two 12-hour shifts, while some mines in South Africa operate two 10-hour or 11-hour shifts. Examples of 12 hour shift systems are 2D-2N-4O, 4D-4O-4N-4O, and 7D-7O-7N-7O (where D refers to ‘day’, N ‘night’ and O ‘off’) (Baulk *et al.*, 2009). Examples of shift systems in South African mines, include three production crews operating two 10.5-hour shifts on a 14-7 (7D-7N-7O) system, or

a system in which no mining work takes place on Sundays (6D-7O-6N-1O) (Mabuza, 2007; Theron, 2014). An example of an 8-hour shift cycle is one which requires four crews on a 7D-5O-7A-1O-7N system (where A refers to 'afternoon') (Stenzel, 2002).

The "one size fits all" concept is not always true when it comes to shift rosters. In other words, there is no single best shift schedule that can be effectively utilised at each and every mine. Shifts of different lengths have advantages and disadvantages, which need to be considered in shift schedule design. While conflicting findings are evident in literature, advantages of extended (e.g., 12-hour) shift lengths might include improved productivity, improved communication at shift changeovers, reduced sick leave, and improved employee morale (Baker *et al.*, 2003). Meanwhile, disadvantages of extended shifts could include fatigue, impaired performance, and increased rate of incidents (Baker *et al.*, 2003). Shift cycles should be designed to minimise fatigue, optimise OHS performance and optimise productivity (Ngobese, 2017; Pickering *et al.*, 2010; Smith *et al.*, 1998; Stenzel, 2002). Numerous factors, in addition to shift length, should be assessed to determine the most appropriate shift system for each operation, and are discussed further in this document. In order to understand the advantages and disadvantages of a particular shift roster, it is important to simultaneously review three key shift roster design parameters (operational requirements, employee needs and OHS requirements).

5.2.3. Operational requirements

The departure point in developing an optimal shift roster is the determination of the operational requirements. The following generic factors should be considered during the exercise of understanding the business needs.

i. Understand the gaps of the current shift roster

It is critical to understand the key gaps or constraints within the current shift roster. The other elements in the system would then be considered in relation to the identified constraints and the performance improvement efforts will focus on optimising the whole system, rather than the identified gaps only. The variance between the total available and actual operating hours is a result of numerous factors such as meal breaks, shift changes, re-entry time, maintenance, breakdowns, absenteeism, training and leave. A detailed analysis of each downtime cause will provide a better insight on the nature of the required intervention.

ii. Define the goals and key performance indicators (KPIs)

In most cases, the requirement to review shift rosters will be necessitated by the need to achieve performance improvement in areas such as productivity, profitability and OHS. Once the gaps of the current shift roster are understood, it is important to define goals and KPIs which will be achieved by changing the shift roster. Appropriate KPIs must be developed to track and monitor the effectiveness of the shift roster change. The goals and KPIs must be specific, measurable, achievable (or attainable), relevant, and time-bound (SMART). Typical goals may include:

- Improving OHS;
- Increasing productivity (increase the number of annual productive work days, productive blasts, face advance per blast, development rates, mineable face length, etc.);
- Increasing equipment utilisation;

- Reducing operational costs;
- Increasing profitability; and
- Optimising the utilisation of labour.

iii. Determine the labour requirements

Labour resourcing should be based on workload and practical evidence, such as data from time-motion studies. The labour resources must be adequate to complete all the required work tasks and other ancillary activities such as making safe and conducting OHS risk assessments. In other words, the right workforce size must be availed on all shifts to support the attainment of all planned conformant blasts. The labour sizing exercise must also consider travelling times and the total available face time. An incorrectly sized team is costly: an under-planned team is likely to result in excessive overtime and lost blasts, and an over-planned team will result in unnecessary overhead expenditure and idle labour time.

iv. Labour staffing ratio

Staffing ratio refers to the number of employees covering a particular vacancy, and the ratio ranges from one to six or more employees per vacancy, depending on the shift rosters (Coleman, 1995). The staffing ratio can provide an indication on the cost effectiveness of the shift roster i.e., whether the roster is over or understaffed. The correct staffing ratio for the ideal shift roster shields the workforce from excessive pressure and fatigue, resulting in improved productivity and OHS.

v. Expertise balance

It is critical to ensure the availability of the right expertise at the right work place and right time. Thus, a skills balance should be maintained on all shifts all the time. A common pitfall is putting less skilled employees on back shifts (e.g., night shifts), resulting in low productivity, sub-standard work and poor OHS performance. Absenteeism due to a number of reasons is always inevitable, thus enough contingency must be allowed to ensure the availability of critical skills all the time. Typical best practices include the use of buffer / multipurpose crews and standby machine operators.

vi. Supervision

A review of the working arrangements of supervisors and management will be necessary. Adequate supervisory staff must be provided to ensure the production, quality and OHS targets are met, and to provide support to the workforce. Moreover, at least one supervisor with the necessary expertise must always be available to oversee all operational activities.

vii. Enhancing effectiveness and utilisation of labour

It is important to put in place measures to maximise the effectiveness and utilisation of labour on all shifts. Potential interventions include effective supervision, practical training and coaching. Use of real-time information management systems (RTIMS) will assist to improve the effectiveness of supervision, utilisation of labour, and will expedite decision-making. Typical RTIMS may include personnel tracking, video cameras, fatigue monitoring and voice communication. Training initiatives must focus on improving the competency and skills of the workforce, multi-skilling, on-the-job training and creating an understanding of basic mining business principles. A training schedule should be developed and incorporated into the shift schedule. Moreover, efforts must be made to improve team morale and cultivate a high-

performance work culture within the workforce. An output-based incentive system, that is understood by all stakeholders, and supported by transparent communication of the outputs, is advocated.

viii. Enhancing work teams

The majority of shift work-based operations tend to promote crew work rather than team work. It is critical to promote team work within the different crews to facilitate the sharing of ideas. Moreover, the use of self-directed work teams (SDWT) will potentially lower costs and improve operational efficiency, mainly by expediting decision-making. An effective shift roster must be designed with due consideration of a number of day-to-day activities such as training, productivity improvement initiatives, meetings and OHS requirements. This will avoid unnecessary schedule disruptions, which result in production loss and increased operational costs.

ix. Communication

Proper communication channels must be established to boost employee morale, avoid duplication of efforts, avoid recurrence of errors, and facilitate sharing of knowledge and experiences. Potential best practices to bridge this gap includes increased management interactions with crews on all shifts, use of log books, shift handovers, hot shift changeovers, and having regular communication meetings, preferably at the start of the shift. Recent technological developments can also be utilised to facilitate effective communication between management and the crews.

x. Shift length

The shift length should be sufficient to allow completion of all the required work tasks, including secondary activities such as making safe and OHS risk assessments. The shift length should also consider other parameters such as mining method, mine infrastructure, travelling times, breaks, physical work demands, fatigue, ergonomics (equipment and workplace) and prevailing mine environmental conditions such as humidity, temperature, noise and air quality.

xi. Support services

Sufficient support services, particularly sound maintenance practices, must always be provided to ensure asset integrity and optimum utilisation of equipment. Potential best practices include adopting preventative and predictive maintenance, scheduling maintenance into the production calendar, having a complete maintenance crew operating on all mining shifts, use of cross-trained operator-maintenance artisans, and the scheduling of most of the maintenance tasks during day shift. Other support services that must be reviewed to ensure efficient shift crew operations include mine services, supply chain, geology, survey, rock engineering, human resources and OHS management.

xii. Optimise the utilisation of equipment

In order to maximise the utilisation of equipment, the mines must strive to operate continuously, i.e., 365 days a year, 7 days a week and 24 hours a day. Continuous operations present the mines with an opportunity to increase productivity, through optimum utilisation of current equipment. Alternative shift rosters, optimal calendar working arrangements, including working on weekends and public holidays, will be determined at mine level. This must be underpinned by a robust value proposition demonstrating the envisaged benefits of the

proposed shift roster and work arrangements. Moreover, mines should avoid shutting down operations completely during weekends and public holidays, as restarting is timeous and costly.

xiii. Ore reserve availability

The backbone of any mining operation is the availability of ground to mine, with the right quality of ore and at the right time. In order to ensure availability of ore reserves all the time, the mines must have sufficient buffer faces to mine and maintain a minimum of 18 months ore availability period (Sebutsoe and Musingwini, 2017). The use of accelerated ore reserve development technologies must also be investigated for implementation.

xiv. Logistics and inventory control

An efficient transportation system for the workforce, materials and mining consumables is critical for an efficient mine production system. Sound inventory control is also key to ensure that the required material is available at the right place and at the right time. Potential best practices include the use of underground buffer stores utilising scanning technologies for controlling inventory levels, use of asset tracking, proper planning and scheduling, and investigating alternative, efficient transportation systems.

xv. Underground facilities and infrastructure

A review must be undertaken to ascertain the adequacy of underground facilities and infrastructure to support the proposed shift roster and work arrangements.

xvi. Legal requirements and guidelines

Shift work and working hours are subject to regulations, and key pieces of legislation covering shift rostering at mining operations in South Africa include the:

- Mine Health and Safety Act (MHSA), 1996;
- Occupational Health and Safety Act (OHSA), 1993;
- Basic Conditions of Employment Act (BCEA), 1997;
- Code of Good Practice on the Arrangement of Working Time, 2017; and the
- Guideline for mandatory code of practice for risk-based fatigue management at mines, 2014.

Employers are required to evaluate work schedules to ensure that the health and safety of employees will not be at risk. The MHSA and OHSA indicate requirements for employers to conduct a risk assessment, implement measures to eliminate or control identified hazards, and train and inform employees about the risks and controls. The BCEA includes factors such as ordinary hours of work, overtime, compressed working weeks, averaging the hours of work, meal intervals, daily and weekly rest periods, and pay for work on Sundays, night work and public holidays. Exemptions in terms of collective agreements can be provided, subject to provisions.

The Code of Good Practice on the Arrangement of Working Time relates to shift work, night work, and rest periods during working time, and provides information about the impact of working time arrangements on the health, safety and family responsibilities of employees (South Africa, 1997 and 1998). The Guideline for a Mandatory Code of Practice (COP) for Risk-

Based Fatigue Management at Mines assists employers to prepare a risk-based COP on fatigue management (South Africa, 2014).

xvii. *Regional requirements*

Blasting times could be affected by changes in shift cycles, which could result in different blasting times for mines in the same areas. As a result, it will be important to consider neighbouring mines and communities in relation to the induced seismicity and re-entry periods.

5.2.4. Employee needs and OHS requirements

Shift work is associated with disturbed sleep, fatigue, impaired alertness and performance, occupational accidents and incidents, health problems, and negative effects on social and domestic activities (Baulk *et al.*, 2009; Greubel *et al.*, 2016; Härmä *et al.*, 2018). These risks could lead to economic losses resulting from increased sick leave and staff turnover rates (Greubel *et al.*, 2016). Shift work could be associated with sickness absence because of work-family conflict and perceived health (Jacobsen and Fjeldbraaten, 2018). Absenteeism has also been attributed to lengthy work hours, fatigue that results from shift length and/or environmental conditions in the stope, and commutes to and from home (Rupprecht, 2018).

i. *Fatigue*

Fatigue is an OHS hazard, and is a causal or contributing factor to many occupational incidents in the mining industry (Hodgskiss *et al.*, 2015; Pelders and Nelson, 2019a; Schutte, 2010; Theron, 2014). Fatigue results in reduced performance and productivity, increased error rates, and can also result in health and psychological problems such as heart disease, hypertension, diabetes, digestive problems, anxiety and depression (Bates, 2009; Pelders and Nelson, 2019a; Pfeifer, 2017; Schutte, 2010; South Africa, 2014; Theron, 2014).

Fatigue risk is inherent in shift work. Shift work, or work performed at unusual times, results in misalignment of the circadian rhythm (or “body clock”) with activities and sleep schedules, which contributes to fatigue or sleepiness at work (Greubel *et al.*, 2016; Kalmbach *et al.*, 2018; Schutte, 2010). Shift cycle characteristics that are associated with the risk of fatigue and incidents include the time of day, direction and speed of shift rotation, consecutive hours on duty, number of consecutive shifts, breaks between work periods, rest breaks during work, and job demands. In particular, factors associated with higher risk of fatigue and accidents include early morning or night shift work, backward rotating shifts, long shift durations (e.g., 12-hour shifts), too many consecutive shifts, a lack of rest breaks, and excessive overtime and on-call work (Bates, 2009; Greubel *et al.*, 2016; Härmä *et al.*, 2018; Kalmbach *et al.*, 2018; South Africa, 2014; Spencer *et al.*, 2006; Theron, 2014). Related recommendations to reduce risks associated with fatigue, health, safety and wellness associated with shift work include:

- Avoid excessive regular overtime and on-call work;
- Avoid backward rotating shifts (e.g., night to afternoon to morning);
- Avoid shift rosters with irregular or unpredictable patterns;
- Avoid working numerous consecutive shifts (e.g., more than four 12-hour night shifts);
- Provide at least 36 hours off following a period of night shift work;
- Ensure appropriate rest breaks within each shift; and
- Address the unique conditions of each operation in fatigue management programmes.

Fatigue and accident risks associated with different shift schedules can be modelled using tools such as the HSE Fatigue Index (<http://www.hse.gov.uk/research/rrhtm/rr446.htm>). The developers of this tool noted that it is useful to assess risks of fatigue and injury, but that it should not be relied on as the only or main way of assessing these risks. They also noted that the tool does not take into account factors such as specific work-related issues, individual differences, or social factors that may affect workers' tolerance to shift work.

ii. Health and wellness

Health and safety risks can result from shift work and fatigue, while medical conditions can also lead to fatigue. These conditions include sleep disorders, chronic pain, tuberculosis, HIV/AIDS, heart problems, thyroid disorders, and certain medications (South Africa, 2014; Theron, 2014). Psychological causes of fatigue include depression, anxiety, stress, and grief (Theron, 2014). Personal factors, such as chronotype (i.e., morningness or eveningness), also affect fatigue associated with shift work (Di Milia *et al.*, 2011). As medical conditions and psychological issues are associated with fatigue, these need to be appropriately managed in the context of shift work. In addition, occupational exposures, such as to radiation, silica, diesel particulate matter and heat, associated with changes in shift schedules should be monitored and managed.

iii. Work environment

The work environment impacts the risk of fatigue and accidents during shift work. Factors associated with high risk include heavy physical work, sustained effort, complex tasks, critical monitoring tasks, or repetitive and monotonous tasks (Baulk *et al.*, 2009; South Africa, 1997 and 2014). Safety-critical tasks should not be undertaken when employees are likely to be fatigued (e.g., during night shifts, 12 hour shifts, or when performing work with high physical or mental demands, or repetitive or monotonous work). Temperature extremes, excessive noise, work stress, poor design of workstations and equipment, and long walking distances in underground workplaces can also contribute to fatigue (Hodgskiss *et al.*, 2015; South Africa, 2014). As such, work environment factors such as lighting, noise, and temperature should be appropriate for worker health, safety, and comfort. The work environment, facilities, equipment, and shift length should be compatible with the anatomical and physiological compositions, and psychosocial needs of all of the workers, including women in mining (van Aardt *et al.*, 2008; Zungu, 2012). The availability of appropriate resources, including staffing and equipment, should also be ensured. Additionally, management services should be available for employees working outside of ordinary hours (South Africa, 1998). These services include first aid, safety supervision, occupational health, emergency services, security, administrative services, transport, eating facilities, and change-rooms, along with training and education and union or committee activities.

iv. Socioeconomic factors

Socioeconomic factors, living conditions, commuting times, and lifestyle-related factors can contribute to fatigue. Sleep length might vary because of economic incentives that compete for time, while shorter daily sleep times and higher sleeplessness have been reported for those with higher general stress, higher education, and higher wages (Pfeifer, 2017; Szalontai, 2006). Financial problems have been identified as a major cause of stress of mine workers in South Africa, and could also result in mine workers working extended hours for bonus or overtime pay (Hodgskiss *et al.*, 2015). Mine workers commonly have a high number of dependants (Theron,

2014). Financial constraints can also limit the quantity and quality of food that mine workers eat (Theron, 2014). Furthermore, living conditions can contribute to the health and fatigue of mine workers, and can affect the ability of workers to obtain adequate sleep, especially at unconventional times of day as required by shift work (Hodgskiss *et al.*, 2015). Inadequate sleep can result from exposure to environmental conditions such as light, noise, temperature extremes, and overcrowding (Hodgskiss *et al.*, 2015). Many mine workers in South Africa reside in informal accommodation, lack access to basic amenities such as running water, electricity, and sanitation, and share rooms with a number of other people, which can have an impact on OHS (Theron, 2014). As such, the living conditions of workers should be considered when scheduling shift cycles. Additionally, as poor nutrition is associated with fatigue and health, consider the supply of meals or supplements for workers. The impact of restrictions to the amount of food that workers are allowed to take underground, as a result of illegal mining, should also be considered.

v. Social and domestic responsibilities

Shift work can result in desynchronization with social participation and increased risk of poor work-life balance (Brown *et al.*, 2010; Greubel *et al.*, 2016). Although the use of 12-hour shifts poses increased safety risks, compressed working weeks could be favourable as this allows for longer periods of time off for social and domestic interaction and leisure time, and results in a reduction in total commuting time (Baulk *et al.*, 2009). Another factor to consider is that workers could undertake second jobs during time off work (Baulk *et al.*, 2009). Lifestyle factors, such as activities outside of work and family commitments, such as poor diet or nutrition, a lack of exercise, drug and alcohol use, can also contribute to fatigue (Hodgskiss *et al.*, 2015; Pelders and Nelson, 2019a; South Africa, 2014; Theron, 2014). Women could potentially have domestic responsibilities than men (Pelders and Nelson, 2019b). Rupprecht (2018) noted that lengthy work hours often prevented mine workers from completing personal chores, which could further result in absenteeism. Additionally, factors such as sleep routines, maintaining healthy diets, and exercise and recreational activities can affect how employees adapt to shift work (South Africa, 1998 and 2014). As such, shift work should be scheduled to optimise employee work-life balance.

vi. Commuting times

Commuting times, including time to travel from home to the mine and back again, and month-end travelling to and from labour-sending areas, can have an impact on health, safety, absenteeism and fatigue outcomes (Brovko *et al.*, 2017; Pfeifer, 2017; Rupprecht, 2018; Sanqu, 2016). Workers with longer commutes have been shown to achieve less sleep during the work week, be less productive at work, and have significantly higher absenteeism rates (Pfeifer, 2017; van Ommeren and Gutierrez-i-Puigarnau, 2009). Theron (2014), for example, noted that employees' days commonly start at 3 am to catch public transport to start work at 6 am, and might only arrive home at around 5 pm. This limits the time available for workers to attend to household responsibilities and to sleep (Hodgskiss *et al.*, 2015; Pelders and Nelson, 2019a; Theron, 2014). Previous research in the SAMI revealed that over half of the participating mine workers usually obtained less than 6 hours of sleep in the 24 hours before a work shift (Hodgskiss *et al.*, 2015). Facilitated transport was advised to reduce fatigue associated with shift work (Hodgskiss *et al.*, 2015). The BCEA (Act No. 75 of 1997, Section 17) indicates that night shift work is subject to the availability of transport between employees' places of residence and the workplace (South Africa, 1997). As commuting time impacts on fatigue, accident risk, and

absenteeism, the regulation or provision of transport could help to mitigate risk. It is also important to ensure that work and transport arrangements allow for continuous sleep of seven to eight hours in each 24-hour period.

vii. Stakeholder engagement and change processes

Shift roster design must be sensitive to the impact on employees and their families (South Africa, 1997 and 1998). Employee needs and preferences for different shift system elements, health and safety impacts, work-related aspects, transport options, and childcare needs should be considered. Employees should also be provided with information about strategies that might assist with coping with shift work (South Africa, 1998). Similarly, fatigue management is a joint responsibility of employers and employees, and active participation from all stakeholders should be encouraged (South Africa, 2014; Schutte, 2010; Theron, 2014). If changes in shift schedules are required, good change management is important for successful implementation, and this would involve consultation, and securing buy-in, commitment and support from all stakeholders (Peetz and Murray, 2010).

5.3. Implementation of new shift rosters

The process of implementing a new shift roster is equally as critical as developing the new shift roster. The implementation of new shift rosters in a mining set-up is a fundamental change which must be properly planned, executed, managed and continually improved. The following section highlights some of the critical considerations for successful implementation of new shift rosters.

5.3.1. Change management

In order to enhance the chances of success of implementation of the new shift roster, it is critical to develop and implement a proper change management strategy. Change management mitigates potential threats that may result in failure of the new shift roster, such as resistance to change by the stakeholders, poor productivity, and poor OHS performance. To this end, a change management strategy was developed, under the auspices of the SATCAP program, to assist the mining industry to address people-centred issues that may hinder successful implementation of new shift rosters.

5.3.2. Continuous improvement

Shift rosters are seldom static. They rather must be reviewed to ensure they remain optimum, as and when operational conditions change. The Plan-Do-Check-Act (PDCA) management model is an important tool that can be used to plan, develop, implement and continually improve the new shift roster. It is critical to note that the PDCA process is not a once-off procedure but a continuous process improvement tool, which is applied continuously throughout the life of the mine. All the elements of PDCA process are linked and interact with each other making the approach systematic and more sustainable.

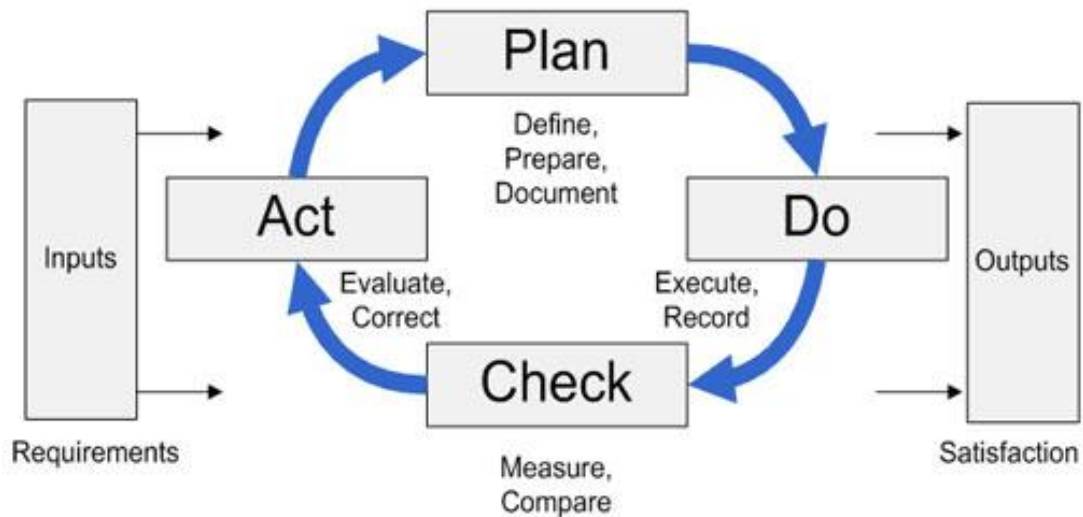


Figure 30: Plan-Do-Check-Act management model (adapted from IOSH 2014)

5.4. Conclusion

This framework can assist mining operations to optimise shift systems, to enhance operational and OHS performance. Mines must strive to operate continuously (i.e., 365 days a year, 7 days a week and 24 hours a day). Continuous operations will potentially enable the mines to improve productivity, through optimum utilisation of current equipment, without incurring capital expenditure. Shift schedules and working arrangements should be determined at mine level, and this must be underpinned by a robust value proposition demonstrating the envisaged benefits. Operational requirements that should be assessed include face time and ancillary activities, goals and KPIs, labour requirements, skills balances, adequacy of supervision, support services, logistics, facilities and infrastructure, management systems, team work and communication. The shift rosters should be designed to minimise fatigue, OHS and psychosocial risks. The work performed and the working conditions might contribute to these risks. Shift cycles should also be designed with consideration of social and domestic responsibilities, lifestyle, income and living conditions, and commuting times. Legislation and regulations relating to shift work also need to be considered. Successful changes in shift rosters will require satisfactory stakeholder engagement and change management processes, and continued monitoring and evaluation is important for successful implementation.

6. Workshop

6.1. Background and purpose

A workshop to discuss the draft framework for optimising shift cycles in the South African mining industry was held at the Mandela Mining Precinct on 25 October 2019. This workshop formed part of the project on *Shift Cycles and Productivity* that was commissioned by the Longevity of Current Mines (LoCM) programme of the South African Mining Extract Research, Development and Innovation (SAMERDI) initiative. Findings from a related project on *Change Processes and Stakeholder Engagement for Shift Cycles Appropriate to Modernisation* that was conducted in the Successful Application of Technology Centred Around People (SATCAP) programme were also incorporated. The purpose of the workshop was to present the findings of the research and to request input into the draft framework on the topic. The invitation and agenda for the workshop is attached in Annexure D.

The target participants of the workshop were representatives from industry (e.g. mine human resources, production, and safety/planning personnel), and Mandela Mining Precinct research partners, programme managers, steering committee members and co-directors. The focus of this initial industry workshop was to gain technical input into the draft framework. It was highlighted that it is vital to obtain input from further industry stakeholders, including each of the recognised unions in the industry, prior to finalising this framework or guideline documents.

6.2. Overview

After welcoming the participants, the programme for the workshop included presenting and discussing an overview of the results of the research, discussing and gaining input on the draft framework, and a wrap-up and discussion of the way forward for the work. The presentation included findings of the literature review of previous work on the topic, and findings of two case studies relating to the shift cycles at two mines in South Africa. The framework for optimising shift cycles incorporated components relating to operational requirements, health and safety matters, employee preferences, and change processes.

Useful input into the framework was provided from the participants. Where feasible, this input was incorporated into the current draft framework. Further input will be used towards informing future research needs. The findings from the workshop were grouped into themes for coherence of this document.

6.3. Shift scheduling

The means to identify an optimal shift cycle was discussed. It was noted that as a starting point it was important to identify the main driver, or ‘constraint’ that needed to be removed or adjusted, then implemented to indicate improvement of that specific element in order to optimise the whole system. The other elements in the system would then be considered in relation to the identified constraint. It was suggested that ‘theory of constraints’ work be linked with this work on shift schedule design. Furthermore, it was noted to be important to balance

employer and employee needs, as these were sometimes conflicting. This goal, and the means to fulfil the goal, would need to be determined by each organisation – this would help to create ownership of the plan, in addition to making business sense. It was evident that every mine is different, and infrastructure and travelling times would play a role in determining appropriate shift cycles. It was noted that the shift cycle was dependent on the set-up of the mine (e.g. narrow-vein versus open pit operations), and the whole system for each mine would need to be assessed.

It was questioned whether the aim of shift scheduling changes was to achieve planned conformant blasts, as per operational requirements. In addition, it was suggested that the aim of the project be to optimise the whole system, rather than only the utilisation of equipment. Another mentioned aim was to make more money both now and in the future.

The mining cycle needs to be assessed, along with the gaps in current shift rosters and causes of lost production time. Risks associated with shift work were discussed. It was noted that although longer shifts (e.g. 12-hour shifts) could be associated with higher fatigue or accident risks, having shorter shifts (e.g. 8-hour shifts) sometimes meant that employees were not able to complete their required tasks in time. Therefore, having shorter shifts could result in workers not completing safety tasks appropriately (e.g. meetings, examinations and making safe), to complete production tasks, which could result in increased risk. As such, longer shifts could help to reduce this risk, and enable the workers to complete their daily tasks.

In terms of a diagram included in the draft framework, it was noted that 'legal requirements' or 'company standards' could be incorporated into the 'operational requirements' factor. It was noted that 'regional requirements' should also be considered. Blasting times could be affected by changes in shift cycles, which could result in different blasting times for mines in the same areas. As a result, it will be important to consider neighbouring mines and communities in relation to the induced seismicity and re-entry periods.

Annual leave, and days off for workers within the mining cycle, were considered. Furthermore, Christmas breaks were discussed, which require stakeholder engagements to be appropriately managed. It was also noted that operations should be cautious about shutting down completely over these periods, as restarting is timeous and costly.

6.4. Maintenance and redundancy

Maintenance strategies relating to shift work were discussed. Preventative and predictive maintenance was recommended to reduce downtime. It was noted that maintenance should be scheduled properly into the production calendar. These shifts needed to be carefully scheduled to streamline the work done. This maintenance includes that of infrastructure maintenance. It was noted that maintenance can work hand-in-hand with production. Although overtime to attend to breakdowns could be avoided if similar shifts were worked by engineering and production personnel, it was noted that it could be helpful if these teams worked different shifts, as the maintenance team then did not need to stop production in order to maintain equipment.

Sufficient redundancy was also recommended, such as extra equipment, spare faces to mine, and labour availability. For example, redundant equipment could be used when the primary equipment was being serviced. Staffing levels needed to be optimised, and it was noted that there was a fine line between determining the appropriate staff levels and when overtime work was appropriate. Properly implemented labour planning can help to increase productivity. In addition, labour planning would be affected by changes in shift cycles. For example, more workers would be required if increasing the operational hours of the mine.

6.5. Fatigue and commuting times

Fatigue was discussed in relation to shift work, and activities performed outside of work. Participants noted that road accidents and fatalities of mine workers occurred while travelling to and from the mines. This risk was particularly apparent following long shifts (e.g. 12-hour shifts), and for those who had long distance commutes. This led to a loss of skills. Additionally, it was identified that the long commuting times, along with the working hours, resulted in workers already being fatigued when arriving at work. Activities performed outside of work, such as having home businesses, could also contribute to this fatigue. An example was noted of how the instalment of an ATM at a mine shaft helped to address the issue of absenteeism, so that employees did not need to take time off work to be able to go and do banking in town during working hours.

The impact of the nature of work performed, such as between conventional and mechanised mines, would have an impact on fatigue. For example, boredom as a result of doing monotonous work was a factor that could contribute to fatigue.

6.6. Illegal mining and nutrition

Illegal mining was noted to have a potential effect on worker fatigue, as a result of food bans. Workers were restricted in terms of food that they could take underground so that it would not be sold to illegal miners. This could result in malnutrition. It was noted that to appropriately manage workers with health problems, including diabetics, these workers could be allowed to take more food underground, or be relocated to work on surface.

Mid-shift feeding was expected to potentially mitigate fatigue. However, it was noted that mid-shift feedings was not always feasible, such as in underground, conventional mines. Another participant suggested that it could help if workers were fed before they started their work. The fitness and diet of workers affects their performance.

6.7. Occupational medicine and wellness

An identified gap in the draft framework related to occupational health and hygiene elements, including exposure to radiation, silica and diesel particulate matter. This is because the occupational exposure (and associated limits) would be affected by an increase towards 12-hour shifts. It was recommended that occupational medical practitioners be involved in further work relating to the development shift work guidelines. It would be beneficial to take a proactive rather than reactive approach, and ensure employees are fit for work.

Health problems of workers needed to be considered, and specific issues addressed in relation to shift work and fatigue. Illness and diseases prevalent among mine workers included obesity and hypertension, which could further be associated with diet and fitness. Other concerns were HIV and TB prevalence among the workers. Those with diseases could have an increased health and safety risk, in relation to shift work. The health, safety and security of women in mining in relation to shift work were also noted. It was also mentioned that the psychological effects of shift work need to be considered. Furthermore, changes in shift cycles can affect worker wellness.

6.8. Managing and monitoring change

It was noted that it was important to have certain steps in place to implement change (i.e. an implementation strategy). In terms of managing change relating to shift schedules, it was noted that consultation was important at the early stages. Cost-benefit analyses would also be needed. It was mentioned that conditions of employment would change if continuous operations were implemented. Additionally, the Mining Industry Occupational Safety and Health (MOSH) adoption process for leading practices was recommended as a vehicle to facilitate the implementation of new shift schedules.

Albert de Beer had led a related project on *Change Processes and Stakeholder Engagement for Shift Cycles Appropriate to Modernisation* and was asked to briefly present recommended processes for appropriately managing change. The need for good planning and communication was highlighted. Co-creation was considered vital, as there could be problems during the implementation of shifts designed solely by management. Various solutions should be considered. The reward system would also need to be discussed through collective bargaining.

It was noted that the rewards systems used would need to be studied further, to ensure that it is economical. Another consideration for further research related to the age of the workforce. Older workers could be more resistant to change than the younger workers. Continued research regarding the process of implementing changes to shift cycles would be valuable.

The need to ensure the shift configuration is properly implemented, and to monitor the effects of changes in shift cycles was discussed. Monitoring and control will help to maintain the benefits of the change and prevent the reversion to old habits. If unintended consequences of the change are noticed, these should be addressed quickly and rectified. For example, absenteeism patterns have been noted to change with changes in shift cycles. Means to assess compliance were necessary, and this should be considered when designing the shift cycle change. Measures could include those for health, safety and productivity performance. Specific indicators under each of these factors should be identified. Sources of lost production can be identified, while compliance, and leading and lagging indicators, can be identified for health and safety. The development of a toolbox of different tools that could be used for monitoring and evaluation was recommended. Simulation software was noted help to assess the consequences of shift cycles. The use of real-time information monitoring systems were also discussed.

Some mines implemented monitoring systems at different places inside mines, including clocking in at waiting places, to track where employees were during the shifts. This helped to manage the effective use of time during the shifts. Close-out meetings at the end of shifts were

also mechanisms that could be used. Ensuring that employees left the workplace at the same time was also noted which helps to reduce pedestrians in haulages at different times. It was noted that systems drive behaviour, which drive culture. Another participant noted that it was important to empower teams to be self-directed, to promote ownership within the crews.

Monitoring systems could help to reduce fatigue and medical-related fatalities. This could further assist to prevent operation shut downs. Participants noted that some mines (e.g. Kumba) used monitoring systems, such as cameras to monitor risks relating to driver fatigue. Heart rate monitoring, and the use of 'smart' watches was discussed. Smart watches could be useful to monitor health hazards, and identify levels of fatigue induced at work and outside of work. These devices can quantify aspects such as sleep obtained, and whether appropriate breaks are taken,

Further research could be performed to assess best practice, and successes with regard to changes in shift cycles, and the implementation of monitoring systems for employees. People-related factors should be assessed. Meanwhile, it was noted that value could also be gained from assessing failures, or 'worst practice' examples. In addition, an assessment of practices in other countries and in other industries that use shift work was recommended.

6.9. Sindisa gold project

It was noted that it was important to revisit the Sindisa project, and link it to other projects. This project incorporated the need to move towards mining continuously to improve productivity. The Sindisa project was conducted in the industry previously, but it did not reach the Department of Mineral Resources, because not all of the unions agreed on the outcome. However, it was noted that there were gaps in this work as it did not consider all elements (e.g. human factors and fatigue). Following the initial discussion, the co-director of the Mandela Mining Precinct, Alistair MacFarlane, presented an overview of findings from the Sindisa Gold Project. It was suggested that Robbie Lazare, a leader of the Sindisa project, be invited to discuss this work further.

6.10. Way forward

The guideline to define the technical aspects is yet to be finalised. The information obtained through the workshop has been incorporated into the framework, which is to be shared with the workshop attendees and the Technical Steering Committee. Once everything is aligned to the outcome of the framework, the project will be handed over to SATCAP programme for further development. The need for co-creation was highlighted, which requires the involvement of all stakeholders in the development of guidelines for shift cycles. This framework would remain as a baseline for further engagements, until participants from labour are involved. Stakeholders include representatives from a range of mines, and labour representatives from each union. The Mandela Mining Precinct has gone through a journey to involve organised labour, who now participate in SATCAP workshops. The need for another workshop with more stakeholders was noted. Furthermore, the need to conduct qualitative research, including interviews with workers, was noted. It was recommended that problems and solutions be discussed with workers.

7. Conclusion

The aim of this project was to draft a framework for the optimisation of shift cycles in the mining industry, while considering productivity and occupational health, safety and wellness outcomes. This aim was achieved through the review of relevant local and international literature, and assessing case studies in the South African mining industry (SAMI). A draft framework was compiled and discussed with industry stakeholders for technical input and recommendations. This framework will be used as a baseline for future work into the development of guidelines for the optimisation of shift cycles in the SAMI.

Recommendations for future work were highlighted. The need to involve all SAMI stakeholders, including unions, government and communities, is important for the co-creation of guidelines for the industry. A future stakeholder workshop is recommended, and could be conducted under the auspices of the Successful Application of Technology Centred Around People (SATCAP) programme. In addition, participation from members involved with the Sindisa Gold Project was recommended. Further work that could be conducted in the SATCAP programme relates to remuneration practices relating to shift work or modernisation, and work relating to the aging workforce in the SAMI. Remuneration issues should also be addressed at mine level.

Further research could involve additional analysis of the processes that have been used by mines when implementing changes to shift cycles. Qualitative research involving mine workers was recommended. Additional input relating to occupational medicine impacts of different shifts would be helpful to refine the shift cycle framework. An assessment of best and worst practices relating to shift cycles, and available monitoring systems and tools would be valuable. Research involving the use of real-time information management and monitoring systems, such as smart watches, is also recommended. In addition, a systems approach, integrating work conducted within the Longevity of Current Mines (LoCM) and broader South African Mining Extraction Research, Development and Innovation (SAMERDI) projects is suggested, as many of the findings could be related for appropriate implementation in the mining sector.

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Annexure A: Data collection tool

Questions for Human Resources and Production / Planning Personnel

Please provide details about the mine, relating to production teams, in the table below

		Example	Current	Previous
1.	Mining method	Underground mechanised room and pillar		
2.	Depth of mining	1 000 m		
3.	Shaft system	Sub-vertical / Decline system		
4.	Shift cycle arrangement (number of daily shifts x hours)	2 x 10		
5.	Blasts per day	2		
6.	How many days per week does the mine operate?	5, 6 fortnightly		
7.	What are the clock-in and clock-out times per shift ('bank-to-bank')?	Morning: 8-6 Night: 8-6		
8.	What is the travelling time from the lamp room to the work place? What are the horizontal travelling distances of the working places? What transport is used (e.g. walk/train)	30 minutes 1km Walk		
9.	What are the average workplace temperatures (e.g. at the stopes)	<28.5°C (WB)		
10.	Re-entry period (hours)	2		
11.	Shifts (days) per month per employee	15		
12.	Total production days per month	28		
13.	Total production shifts per month	56		
14.	Total shift hours per month	560		
15.	Tonnes per shaft per month	16 500		
16.	What is the crew size	13		
18.	Square metres (centares) per crew	350		
19.	Possible working days per annum	352		
20.	Total production days per annum	352		
21.	Employee shifts per annum	198		
22.	Number of employees per crew	12		
23.	Fatality frequency rate	1		
24.	LTI* frequency rate	20		
25.	Average monthly absenteeism per shaft (%) (note if planned and/or unplanned)	6		

* Lost Time Incident (LTI): an incident which results in absence from work beyond the date or shift when it occurred

Data required

- Shift roster (including shift start and end times)
- Shaft schedules
- Clock-in and clock-out times for stoping crews (bank-to-bank)
- Overtime hours worked
- Results of time-motion studies performed, if available (i.e. shift activity durations)
- Labour agreements, if available
- Travelling distance per level
- Lost-blast analysis reports, if available

Question guide

1.1. What are the current shift cycle arrangements at this mine?

1.2. What are benefits of the current shift cycle arrangement?

1.3. What are challenges of the current shift cycle arrangement?

2.1. When last did you implement changes to your shift system(s)?

2.2. Was there consultation before the changes were implemented, and if so what was your experience of it?

2.3. Were the reasons for the changes explained during the consultation and/or communication process?

2.4. Could employee representatives (unions) question the reasons for the changes? If not, why not?

2.5. What did you understand as the reasons for the change?

2.6. Were employee representatives (unions) able to propose alternative arrangements or improvements to the proposed arrangements? If not, what prevented this?

2.7. Were the proposals by employee representatives considered? Examples?

2.8. Did management and employee representatives (unions) jointly decided on a change management plan to implement the changes?

2.9. If there was not a joint change management plan developed, how was the change implemented?

2.10. Was the implementation successful? Give reasons for your answer

2.11. What would you have wanted to be done differently as part of the change process?

2.12. Did the implementation resolve the original problem to be addressed – the reason for the change?

3.1. Is the available face time sufficient to complete the mining cycle tasks (for both day and/or night shifts)?

3.2. If not, why and what are the possible corrective measures?

- 3.3. What is the breakdown between productive and non-productive time during the shift, as far as you are aware?
- 3.4. Approximately how long does it take for workers to travel to their working areas from the time that they clock-in?

- 4.1. How often is overtime worked, and how is overtime managed?
- 4.2. How are working hours and overtime regulated at the mine?

- 5.1. What is the contingency/redundancy plan of the mine in terms of:
- 5.1.1. Labour (to take account of absenteeism, training, sickness, and leave)
- 5.1.2. Equipment (critical equipment)
- 5.1.3. Power (standby generators)
- 5.2. Do you have challenges with compressed air pressure at the face?
- 5.3. What are the bottlenecks in the mining cycles?
- 5.4. Are there any resources at the mine that are inadequate?

- 6.1. What is the maintenance philosophy of the mine (e.g. preventative maintenance during weekends)?
- 6.2. Are the maintenance and mining crews on the same shift cycle arrangement?

7. Do you have the same level of supervision on each shift?

8. Are the support services adequate for each shift?

- 9.1. Is fatigue an issue within your workforce?
- 9.2. What are the main causes of fatigue?
- 9.3. What can be done better to reduce fatigue levels?
- 9.4. Are workers provided with meal breaks during their shift?
- 9.5. Does the mine provide meals and drinking water for workers?
- 9.6. Is heat in the workplace an issue in terms of fatigue?
- 9.7. Where do most of the workers at this mine live, and how far is it from the mine?
- 9.8. What are the living conditions of the workers, and does it affect fatigue?
- 9.9. What mode of transport do the workers use to get to and from home? Does the mine offer transport for the workers?
- 9.10. How long are worker commuting times?

[illegible]

10. What are the opportunities for continuous improvement?

Annexure B: Ethics clearance



CSIR Research Ethics Committee
PO Box 395 Pretoria 0001 South Africa
Tel: +27 12 841 4060
Fax: +27 12 841 2476
Email: R&DEthics@csir.co.za

05 December 2018

Dear: **Mr Navin Singh**

Extension of the validity of the previously approved Protocol: **The South African Mining, Extraction, Research, Development and Innovation (SAMERDI) Programme.**

This is to confirm that the ethical approval validity for this Protocol that has since expired has been extended for another year. The reference number of this research project is REF: 239/2017.

This approval of the extension is granted under the condition that:

1. The researcher remains within the procedures and protocols indicated in the proposal, as well as the additions made to the procedures and protocols as indicated in the responses submitted to the questions of the REC, particularly in terms of any undertakings made and guarantees given.
2. The researcher notes that any deviations to the approved project/protocol must be submitted to the REC for approval before implementation.
3. The researcher remains within the parameters of any applicable national legislation, institutional guidelines and scientific standards relevant to the specific field of research.
4. This approval is valid for one calendar year from the date of this letter.
5. The researcher submit bi-annual progress reports to the REC
6. The researcher immediately alert the REC of any adverse events that have occurred during the course of the study, as well as the actions that were taken to immediately respond to these events.
7. The researcher alert the REC of any new or unexpected ethical issues that emerged during the course of the study, and how these ethical issues were addressed. If unsure how to respond to these unexpected or new ethical issues as they emerge, the researcher should immediately consult with the REC for advice.
8. The researcher submit a short report to the REC on completion of the research in which it is indicated (i) that the research has been completed; (ii) if any new or unexpected ethical issues emerged during the course of the study; and if so, (iii) how these ethical issues were addressed.

We wish you all of the best with your research project.

Kind regards

Prof WA Hoffmann
(CSIR REC Chair)

Ms Brenda Mapunya
(CSIR REC Secretariat)

Annexure C: Shift cycle design element considerations

Shift roster design element	Category	Description	Recommendation
Understanding shift rosters	Shift cycles	<ul style="list-style-type: none"> Assess various shift rosters, taking into consideration all the key shift roster design parameters 	<ul style="list-style-type: none"> Do a cost benefit analysis of different shift lengths and schedules
Operational requirements	Legal requirements and company standards	<ul style="list-style-type: none"> Ensure compliance of the selected shift roster to all applicable legislation 	<ul style="list-style-type: none"> If the shift roster does not comply to certain provisions of the legislation consider the following: <ul style="list-style-type: none"> Aligning the shift roster to legislation Selecting alternative shift rosters Requesting for exemptions from the responsible authorities
	Understand the gaps of the current shift roster	<ul style="list-style-type: none"> Understand major constraints within the current shift roster 	<ul style="list-style-type: none"> Do a detailed analysis of major constraints and suggest suitable interventions
	Define the goals and key performance indicators (KPIs)	<ul style="list-style-type: none"> From the identified constraints, define goals and KPIs which will be achieved by changing the shift roster 	<ul style="list-style-type: none"> Develop SMART goals and KPIs
	Determine the labour requirements	<ul style="list-style-type: none"> Determine the human resource requirements of the shift roster options 	<ul style="list-style-type: none"> Labour requirements should be informed by the workload and practical evidence from time motion studies Ensure the availability of the right expertise at the right work place and right time Avail at least one supervisor with the necessary expertise, to oversee all operational activities on every shift
	Enhancing effectiveness and utilisation of labour	<ul style="list-style-type: none"> Put in place measures to maximise the effectiveness and utilisation of labour on all shifts 	<ul style="list-style-type: none"> Effective supervision <ul style="list-style-type: none"> Avail at least one supervisor with the necessary expertise, to oversee all operational activities on every shift Use RTIMS to improve the effectiveness of supervision, utilisation of labour and expedite decision-making Effective training to improve the competency and skills of the workforce Focus on improving team morale and cultivating a high performance work culture Promote team works and use of self-directed work teams (SDWT) Ensure effective communication at all levels within the organisation
	Shift length	<ul style="list-style-type: none"> Determine the correct shift length 	<ul style="list-style-type: none"> Shift length should be determined taking cognisance of factors such as work requirements, travelling time, OHS requirements and workplace conditions
	Support services	<ul style="list-style-type: none"> Provide sufficient support services to ensure asset integrity and optimum utilisation of equipment 	<ul style="list-style-type: none"> Having maintenance crews operating on all mining shifts Use of cross-trained operator-maintenance artisans Scheduling most of the maintenance tasks during day shift Ensure underground facilities and infrastructure have capacity to support the proposed shift roster and work arrangements
	Optimise the utilisation of equipment	<ul style="list-style-type: none"> Ensure optimum utilisation of mine equipment 	<ul style="list-style-type: none"> Mines must strive to operate continuously (i.e., 365 days a year, 7 days a week and 24 hours a day)
	Ore reserve availability	<ul style="list-style-type: none"> Ensure availability of ground to mine all the time 	<ul style="list-style-type: none"> Maintain a minimum of 18 months ore availability period (Sebutsoe and Musingwini, 2017). Investigate the use of accelerated ore reserve development technologies
	Logistics and inventory control	<ul style="list-style-type: none"> Ensure an efficient logistics and inventory control system 	<ul style="list-style-type: none"> Use of underground buffer stores utilising scanning technologies for controlling inventory levels Use of asset tracking Proper planning and scheduling Investigate alternative efficient transportation systems

Shift roster design element	Category	Description	Recommendation
OHS requirements and employee needs	Fatigue	<ul style="list-style-type: none"> Design shift schedule optimally to reduce the risk of fatigue 	<ul style="list-style-type: none"> Overtime and on-call work should be limited Backward rotating shifts should be avoided Avoid working more than four consecutive 12-hour night shifts Provide at least 36 hours off following a period of night shift work Fatigue management programmes should address the unique conditions of each operation
	Occupational health and wellness	<ul style="list-style-type: none"> Manage the health and occupational exposures of workers 	<ul style="list-style-type: none"> Occupational exposures are affected by shift lengths and should be managed accordingly, such as for radiation, silicosis, diesel particulate matter, and thermal strain. Medical conditions and psychological issues are associated with fatigue, and should be managed in the context of shift work Workers should be able to eat properly, participate in recreational exercise, and be educated about lifestyle factors that can affect their health (e.g., smoking and substance abuse)
	Working conditions	<ul style="list-style-type: none"> Assess working conditions to minimise health, safety and fatigue risks 	<ul style="list-style-type: none"> Safety critical tasks should not be undertaken when employees are likely to be fatigued (e.g., during night shifts, 12-hour shifts, or when performing work with high physical or mental demands, or repetitive or monotonous work) Ensure appropriate rest breaks within each shift Poor nutrition contributes to fatigue, therefore consider the supply of meals or supplements for workers; the impact of restrictions due to illegal mining should also be considered Work environment factors such as lighting, noise, and temperature should be appropriate for worker health, safety, and comfort Appropriate management services should be available to those working outside of ordinary hours Ensure availability of appropriate resources e.g., staffing and equipment
	Socioeconomic factors	<ul style="list-style-type: none"> Consider workers' financial and living conditions 	<ul style="list-style-type: none"> Consider the living conditions of workers, as aspects such as exposure to noise and temperature extremes contributes to fatigue Financial wellness of workers should be considered
	Commuting times	<ul style="list-style-type: none"> Assess the length of time it takes for workers to commute to and home from work 	<ul style="list-style-type: none"> The total amount of time from when workers leave home before a work shift until returning home afterwards should allow for continuous sleep of seven to eight hours in each 24 hour period Consider the availability or provision of transport for workers Consider travel times of migrant workers to avoid high risk when travelling from or returning to work
	Social and domestic responsibilities	<ul style="list-style-type: none"> Ensure that workers have sufficient time between shifts to attend to personal activities 	<ul style="list-style-type: none"> Workers should have sufficient time each day attend to daily responsibilities Workers should have time within their shift schedule to attend to family and social commitments, including shopping or going to the bank Workers should have at least one weekend off per month
	Worker preferences	<ul style="list-style-type: none"> Consider worker preferences in shift schedule design 	<ul style="list-style-type: none"> Consider employee preferences and needs in shift schedule design Provide workers with information or training about shift work, and strategies to cope with irregular working hours Consult with workers before changes to shift cycles are made
Stakeholder engagement and change processes	Stakeholder engagement and change processes	<ul style="list-style-type: none"> Follow a structured change management process, which includes and involves all stakeholders 	<ul style="list-style-type: none"> The following approach has been considered best practice for change management: <ul style="list-style-type: none"> Identify what will be changes/improved Use an inclusive process to arrive at a solid business case Plan for the change Provide resources and use data for evaluation Communication Monitor and manage resistance, dependencies and budgeting risks Celebrate success Review, revise and continuously improve

Annexure D: Workshop invite and agenda



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WORKSHOP ON SHIFT CYCLES AND PRODUCTIVITY

Mandela Mining Precinct, Corner of Carlow and Rustenburg Roads, Johannesburg
25 October 2019, 09:30 - 13:30

PURPOSE

You are invited to participate in a workshop to discuss and provide input into a draft framework for optimising shift cycles in the South African mining industry. The purpose of the workshop is to share information about the findings of the project to optimise shift cycles, and to discuss comments based on the review of the draft framework. The outcome will be a draft framework for shift cycle arrangement optimisation.

BACKGROUND

The South African Mining Extraction Research and Development Initiative (SAMERDI) strategy commissioned a project under the Longevity of Current Mines (LoCM) research programme on *Shift Cycles and Productivity*. Most narrow reef gold and platinum mines are getting deeper, and increased travelling times and activities taking place during the mining cycle reduce the time available to complete work requirements. Optimising shift cycles could help to improve productivity, and occupational health and safety (OHS) in the South African mining industry.

SCHEDULE

Time	Activity
09:30	Arrival, tea and coffee
10:00	Welcome
10:05	Safety moment
10:10	Introduction
10:20	Project overview
10:45	Question and answer session
11:00	Break
11:15	Draft framework inputs and commentary
12:45	Way forward
12:50	Closure and vote of thanks
13:00	Lunch and networking

TARGET AUDIENCE

The target audience for this workshop include mine human resources (HR) practitioners, production personnel, safety/planning team, Department of Mineral Resources, Minerals Council South Africa, Mandela Mining Precinct programme managers, steering committee members and research partners.

RSVP

Please RSVP to Refiloe Maponya (email: rmaponya@mineralscouncil.org.za) by 18 October 2019.

AGENDA

Page 1 of 1

MINDS FOR MINES