

Staying Safe in the Jungles of Borneo: Five Studies of Fatigue and Cultural Issues in Remote Mining Projects

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Abstract: The global mining industry keeps expanding, and projects are often started in areas previously considered too remote. Due to worker beliefs about safety, and the diversity of cultures in remote projects, the measurement and management of human fatigue is complex. This paper reports on five studies from companies in Kalimantan, the Indonesian part of the island of Borneo, where workers had been killed in likely fatigue-related accidents. Mixed-method approaches, involving qualitative, semi-quantitative, and quantitative measures were used. Participants were 20–45 yr old, had homes of 4.7 people ($SD \pm 1.8$), shared income outside of the house in 80% of cases, travelled ≤ 3 d each-way between blocks of shifts. A major output was a set of camp standards to help ensure recovery sleep. Another requirement identified was access to leave when family members died, since not attending death ceremonies caused a lot of stress and made recovery and safe work less possible. Demanding work conditions and long work hours were also problematic in some operations. Safety systems should better consider fatigue in accidents/incidents and link its data with hours of work information. The interaction of cultures, stress, sleep, fatigue, safety and individual differences must be more effectively addressed in remote mining camps.

Key words: Fatigue, Mining, Culture, Sleep, Risk, Remote

Introduction

The global mining industry continues to expand, in terms of both the size and number of projects. As this growth occurs, projects have been commissioned in areas previously considered too remote and/or difficult¹. Communities located near mines often support ‘progress’ because of the economic benefits, but other impacts such as those on safety, culture and the environment are often poorly understood until after a project starts².

To improve the management of fatigue and all safety-related risks, it is considered critical that a more sustainable approach to measuring and managing fatigue is developed³. This was acknowledged by the companies for which the studies in this report were completed, and in all cases the reasons for the studies was related to previous accidents and incidents in which workers were

killed, where fatigue was noted as a causal or contributory factor.

Many large multi-national mining companies have guidance material and policy related to risk-based fatigue management^{4,5}, however the responsibility for implementation of these is often held at a local level, and local factors may not be well addressed in the general guidance material. In relation to fatigue in mining operations some important factors include: workload⁶, individuals differences⁷ including age^{8–10}, heat stress¹¹, and sleep^{12,13}. Living conditions are also a major factor that requires ongoing monitoring and improvement if reducing accidents and incidents is considered as important¹⁴.

Given that hours of work create (or limit) opportunities for recovery sleep, which interacts with other factors including age and living conditions, the amount and timing of work hours is also very important^{15–18}.

The scope of the individual studies reported on in this

paper were different but included key themes. These themes were:

- 1) Safety in continuous (24-h-per-day, 7-d-per-week) operations;
- 2) Sleep/recovery between shifts; and
- 3) Managing fatigue in a diverse context made up of many ethnic groups.

Other themes were also considered in one or more study, which included cultural, religious and role-specific factors, other responsibilities of workers when they were at home between blocks of work, nutrition/energy requirements of workers and methods of communicating safety messages to workers.

The intended objective of this paper was to aggregate the learning from the five studies to report general and specific information that is practically useful for developing implementation guidelines in remote mining settings. It was intended that the information should be useful for measuring and managing fatigue-related factors in a culturally sensitive and sustainable way, to improve safety, quality of life for workers and productivity for the companies.

Methods

This paper reports on five previously unpublished studies conducted in Kalimantan, the Indonesian part of the island of Borneo. The studies were completed between April 1998 and August 2007 for two different coal mining companies, and their relevant contractor companies. Between the studies various qualitative, semi-quantitative, and quantitative methods were used including the following:

- Qualitative (e.g., semi-structured interviews; review of company documentation);
- Semi-quantitative (e.g., measurement of sleep quality and quantity using diaries); and
- Quantitative (e.g., assessment of work hours using a bio-mathematical model; assessment of fatigue-related incident/accident costs).

The main elements of Study 1 were semi-structured interviews with key stakeholders, assessment of relevant company documents – including accident and incident investigation forms, fatigue-related policy and procedures, and risk management guidelines – as well as visits to each type of living camp/facility. Study 2 involved the use of self-report sleep diaries to measure the timing and quality of sleep in each type of living camp/facility. Study 3, which was with the same company from Study 1, also used semi-structured interviews, and also involved analysis of various rosters for fatigue related to hours of work, and assessments of key factors such as the snacks provided on night shifts. Study

4 was a comprehensive analysis of different types of rosters used by the company as well as two contracting companies. Study 5 focused on semi-structured interviews, visits to each type of living camp/facility and the development of camp guidelines to be implemented in remote mining operations. To reduce the total length of this article the qualitative aspects of the studies are only discussed briefly.

Semi-structured interviews

In three of the five studies, semi-structured interviews were completed with a wide range of stakeholders including workers, worker's families, relevant community groups, village leaders, religious and/or cultural leaders, contractor representatives, supervisors and managers. Due to the unique nature of the studies, culturally-sensitive interview templates were developed. There were different templates depending on the individual or group, to ensure a higher relevance of questions to each stakeholder. Interviews were completed with the assistance of trained translators.

Study 1

Interviews were completed with a total of 55 individuals including workers during the night shift (18) and finishing the day shift (13), family members living in company housing (6) and non-company housing (5), Shift Superintendents, (6), Pit Managers (3), Human Resource and Safety Managers (4).

Study 3

Focus groups were completed with four different parts of the mining operation, and covered 5, 6, 6 and 7 participants respectively (for a total of 24). Interviews were completed with 2 contractor company's representatives, with an additional 5 people interviewed in total. Community leaders and groups were also interviewed. In total, 5 leaders of different villages where workers lived between shifts were interviewed, 12 wives were interviewed (in 4 groups), 23 community or religious leaders were interviewed (in 4 groups) and 3 home visits were made with wives and families of workers. Managers and supervisors within different parts of the company were also interviewed, and these interviews added 26 additional people. This led to a total of 97 interviewees not including children of workers. The semi-structured interview templates are available from the author.

Study 5

A total of 20 workers were interviewed individually, or with one other worker present. The roles of the workers were varied, included 5 supervisors/coordinators, 6 logistics workers, 4 geology/exploration workers, 2 administration workers, 1 environmental rehabilitation technician, 1 welder/mechanic, and 1 camp cook. In

addition, there were 4 village meetings, which included between 2 and more than 20 individuals each, which included village and/or religious leaders, as well as community and/or cultural leaders or administrators.

Review of company documentation

The reviews of company documentation were intended to initially understand the policy and procedure environment of the company. The relevant documents assessed by topic included:

- Fatigue, fitness-for-duty, or safety-related policy;
- Procedures related to rosters, hours of work (including management of overtime), contingency plans;
- Risk assessment, and how (if at all) fatigue issues are identified, assessed, controlled and monitored;
- Training, of any sort related to fatigue, fitness-for-duty or related topics; and
- Accident/incident reporting forms and investigation procedures.

Measurement of sleep

For Study 2, a sleep survey was used to collect data from 112 workers during blocks of night shifts. This represented approximately 10% of the workforce. The data was collected using a standard sleep diary (available on request from the author) which collected the worker's name, identification number, department, address and sleep information.

Sleep information was collected for each main sleep and nap during a week of night shift. A main sleep was defined as the longest sleep obtained in each 24-h period. A main sleep generally occurred soon after an individual arrives home from night shift until early afternoon. A nap was considered any sleep that occurred at least one hour after the main sleep finished.

For the main sleep, workers were asked to rate how sleepy or awake they felt just before going to bed and just after waking up. This rating was on a seven-point scale ranging from 1 (Feeling active and vital. Alert and wide awake.) to 7 (Almost in reverie. Sleep onset soon. Lost struggle to remain awake.).

For each main sleep or nap, workers were also asked to record how well they slept on a five-point scale. How well a worker slept was rated as being 1 (Very well), 2 (Well), 3 (Average), 4 (Poor) or 5 (Very poor). Finally, each worker was asked to predict the total amount of sleep they obtained for each day during the week of night shifts. The terms used in this scale were appropriately translated so meanings were understood.

Assessment of work hours

For Study 3 and Study 4 the focus was on analysis of hours of work using a bio-mathematical model for

fatigue prediction. The model, developed and validated over more than a 10-yr period, was used to assess specific work patterns, to indicate likely times and shifts that are high in fatigue related to the hours of work. Validation of this model has included laboratory, simulator and field-based studies^{7, 16–19}. The model has also been commercialized for sale and is known as Fatigue Audit InterDyne (FAID). (Contact the author for any additional information about the model's development, its application in operational environments, and its integration in to a broader risk-based fatigue management system.)

A variety of shift rosters were analysed, including the following for Study 3:

- 6 × day shifts (06:30–15:30) followed by 1 d off; 6 × afternoon shifts (14:30–23:30) followed by 2 d off; and 6 × night shifts (22:30–07:30) followed by 3 d off.
- 6 × day shifts (06:30–18:30) followed by 1 d off; and 6 × night shifts (18:30–06:30) followed by 1 d off.
- 4 × day shifts (07:00–19:00) followed by 1 d off; and 4 × night shifts (19:00–07:00) followed by 1 d off.
- 6 × day shifts (05:00–16:00) followed by 3 d off; and 6 × afternoon shifts (16:00–24:00) followed by 3 d off.

The work rosters assessed for Study 4 included:

- 3 × day shifts (06:00–18:00), 3 × night shifts (18:00–06:00) followed by a single day off.
- 13 × day shifts (0600–1800) followed by 1 off, and 13 × night shifts (18:00–06:00) worked for 12 wk on and 2 wk off.

The model produces a *fatigue score*, which reflects a prediction of work-related fatigue based on the hours of work. The fatigue score produced is a rating ranging from zero to greater than 140. As a practical benchmark, laboratory and simulator studies indicate that performance impairment present in an individual with a score above 100 points is significant and control of fatigue factors is recommended. Scores below 80 points are generally acceptable, and scores between 80 and 100 points may need additional control of fatigue factors (which can be assessed using a risk assessment within each key operation).

Institutional review board requirements

The studies were approved by the human ethics panel at the Queen Elizabeth Hospital or the University of South Australia. All subjects provided informed consent prior to participation in the studies, and were instructed they were free to withdraw from the study at any time without providing reasons.

Results

The following results are a summary of the key findings of the five studies. Due to constraints on the article size, it was not possible to provide all of the results for all of the studies.

Semi-structured interviews

Study 1

A major issue identified was that the ability for workers to get recovery sleep between shifts was largely dependent on where they lived. For this company, all workers lived in close proximity to others; either in local villages with their family, or in camps for single workers from other parts of Indonesia. There were common problems that were reported, which are listed below in order of importance:

- Noise from within the house and neighbourhood;
- Heat, humidity and light;
- Activities competing with sleep such as water collection, prayers, meals, interruptions by family or visitors;
- Stress from company issues such as conflicts with supervisors, or from non-work issues such as sick family members or financial problems, which all made achieving adequate sleep more difficult;
- Overtime; and
- Other jobs in addition to working for the company, or other responsibilities such as farming family land.

The reported average amount of sleep that workers obtained between night shifts was approximately 2 to 5 h per night. This finding led to the sleep diary study reported in Study 2 below. The reported average for sleeps other than those between night shifts was approximately 6 to 8 h per day.

Other key information reported from the interviews and associated site and housing visits included:

- The average overtime being worked per person was 60 h per month, over and above the 40+ hours-per-week being worked on most rosters;
- The quality of food eaten by many workers was poor in terms of nutritional value, and the current company practice of providing a substantial meal – for example, including rice, fish, vegetables and drinks – on night shifts was considered very effective in helping people sustain themselves through the shift;
- Workers often felt that they could not report that they were having problems with fatigue, or other issues, to their supervisor, which communicates a likely problem in the safety culture of the supervisors and possibly in other senior operations staff; and

- Napping was occurring on site, during breaks and at other times, but there was no formal acknowledgment of the practice, which was considered to be potentially very dangerous²⁰⁾ because people could sometimes be woken up and immediately be expected to perform safety-critical tasks such as driving a haul truck in the mining pit.

Study 3

From each of the four focus groups it was clear that workers had a high-level general appreciation for the relationship between fatigue and work place safety. All workers spoken with could describe specific difficulties encountered when trying to sleep during the day. Difficulties can be categorized in to factors arising from the environment (e.g., heat, light, noise), interruptions to sleep (e.g., receiving visitors), delays to sleep (e.g., due to completing chores) and lifestyle issues (e.g., living a long way away from work, working another job or on a family farm).

Some workers outlined possible solutions that there were aware of including: making the work environments as light as possible, rotating between different pieces of equipment, taking regular breaks, moving, eating, drinking of coffee or water, and asking the backup worker or supervisor for a break. Energy drinks that contain caffeine and other stimulants were very commonly mentioned.

Study 5

Unlike with the operations referred to in the results of Study 1 and 3, the operations related to Study 5 were not associated with villages or any non-company housing. All workers in the company related to Study 5 were living as singles (without family present) in remote mining camps. Eight of the 20 interviewed workers had moved to Kalimantan for work reasons, and 18 of the 20 identified themselves as belonging to a specific ethnic group. Not all individuals offered what specific ethnic group they associated with, but the general information collected from questioning around this issue informed the researchers that the main associations (as ethnic group or place or origin) of the 18 individuals that offered an association were very diverse.

When they were not working for the company and living in the mining camp, the places that workers travelled to in order to live were also diverse. Seven major towns and regional cities were named, and between one and seven individuals travelled to these places between blocks of shifts. Travel each way to and from home was reported as being up to a maximum of 3 d, and 2–3 d was common.

The number of people living in the house that each worker lived in, when not working for company, ranged from 2 people to 9 people. On average, there were

nearly 5 people, with a standard deviation of 1.8 people, in each house. It was usual for most of the people, that were additional to the worker, to be the worker's spouse and children, but it was not uncommon for people to live with their parents, parents-in-law, brothers, sisters, or families of brothers or sisters.

In addition to working for the company the individuals interviewed reported significant additional responsibilities were performed when they were at home between blocks of shifts. These often focused around the house and family and not extra paid work.

The length of the typical day of work reported for the majority of workers interviewed depended on their role. The shortest days tended to be for the most physically demanding work, such as drilling crews working in very hot and humid environments without much shade. These workers reported that they normally finished work at approximately 16:00–17:00; an approximately ten-hour day in total. Those working in support roles, including transport and other logistics workers, usually worked longer hours but in less physically demanding environments. That is, they were working in cooler and less physical tasks, although the mental demands of these roles could often be very challenging. These workers reported that they normally finished work at approximately 17:00–18:00 or later; an approximately 11-h day. It was typical for some camp bosses, supervisors and other key logistics workers to regularly work even later than this, to 19:00 or 20:00 after eating dinner, and these individuals would also often have to sleep with a communications radio to be available if there was any need for them across the night, such as an emergency, which was not reported to happen regularly.

The sleep opportunities that workers reported having when sleeping in the camp were quite similar, except for workers in jobs like cooking that have to happen at least partly during normal sleep times.

When asked for their opinion about what the maximum number of people sharing a room should be, the following answers were provided by the 18 workers that sleep in camps:

- Rooms should only be for one person – 1 worker;
- Maximum per room should be 2 or 3 people – 6 workers;
- Maximum per room should be 4 or 5 people – 9 workers; and
- Maximum per room should be 6 or more people – 2 workers.

Not surprisingly, given the range of religions and cultures represented by the interview group, there were many different answers offered to the questions about cultural/religious issues. Eight of the 20 did not report

any essential cultural/religious requirements other than prayer and reading of the Koran or Bible (depending on religion). One person did not want to answer the questions on this topic. Six individuals reported that there were ceremonies that had to be attended; these requirements were always either death-related or marriage ceremonies involving family (and especially close family).

A major reason to meet with the village leaders was to discuss the cultural/religious needs of workers, so that minimum needs and desired allowances could be discussed. Similar questions were asked of the workers, which again allowed for confirmation and cross-validation of reported data. Much of the discussion about cultural/religious needs was general, so that the leaders had as much time as they needed to explain as much about their customs, traditions, ceremonies, religious obligations, etc. as they wanted to. Then, the interview questions progressed in a way that helped the researchers understand which of these were needs, which were simply preferred, and what the specific needs and flexibilities were in terms of timing/logistics.

There were many different types of cultural/religious ceremonies, customs, etc. Without breaking these down in to specific needs at the level of religion, ethnic group, or geography, the major types of ceremonies, customs, etc., from approximate higher to lower importance, were:

- Death ceremonies/customs;
- Ritual ceremonies/offerings for healing, gratitude, protection, etc.;
- Weddings;
- Births; and
- Season change (e.g. harvest), new year, etc.

The most universal type that was considered by all leaders to be a need or “must attend” was the death ceremonies/customs.

Reviews of company documentation

Despite the availability of some corporate guidelines and/or policy about fatigue, very little policy, procedural documentation or other formal systems were in place in any company. Even fairly basic information like planned and actual hours of work was not often stored centrally in a valid and reliable format. This meant that individuals could choose to, or be pushed to, work excessive hours and it would not be noted in the system unless it was associated with an incident/accident investigation. There was, therefore, a significant need for formal procedures related to setting limits on hours of work, monitoring of hours of work, and tracking actions taken to eliminate and reduce excessive hours of work.

The incident and accident reporting forms assessed from the companies all needed substantial review. None

of them collected information that would be adequate to determine the relative contribution of sleepiness or fatigue to incidents or accidents. Example information that could be added to reporting forms and/or investigation templates was:

- The actual hours of work for the previous seven days;
- The individual's estimation of the timing of sleep onset and offset in the previous 24 and 48 h;
- The individual's report on any difficulty staying awake (or the memory of actually falling asleep) during the shift that the incident or accident occurred;
- The average commute time for the individual to and from work;
- The workload and other work demands of any other responsibilities outside of work that the individual was involved in;
- The details of any medications, both prescribed or otherwise, in the 24 h prior to the incident and accident;
- Breaks obtained during the shift during which the incident or accident occurred; and
- In the individual's opinion, any significant life event involving family, finances or health that could have contributed to the event.

Other documentation that could also be of significant value for reducing fatigue-related risks include:

- Checklists for contractors to assess their likely levels of fatigue before they accept any jobs on site (including out-of-hours call-outs and overtime shifts);
- Day of operations risk assessments to better identify, assess, control and monitor fatigue-related risks related to changes such as shift extensions, rest break reductions, etc.;
- Fatigue report forms to allow individuals to identify themselves and/or others as fatigued, to be treated as a hazard identification or near-miss; and
- Audit checklists to help verify that required policy, procedures and monitoring are occurring as required, and that the fatigue management system is getting the desired results (and any areas where more work is needed).

Sleep of night shift workers

The only in-depth Study of sleep performed within the five studies was done in a company using an 8-hour shift system. In Kalimantan it was more normal to use a 12-h shift system so the results of this study, Study 2, are likely to overestimate the amount of sleep that many remote mining workers get. The average quantity of sleep achieved across all of the 112 workers for all

sleep between night shifts was 5.9 h. ($SD \pm 1.4$ h).

Sleep quality was determined from self-report scores on a 5-point quality scale. The question, 'How well did I sleep?' could be answered as 1 -very well, 2 -well, 3 -average, 4 -poor, or 5 -very poor. The average score was 2.1 across recorded main sleeps, indicating that workers assessed that they slept 'well' during these sleeps. ($SD \pm 0.8$ points). Across recorded naps, the average score was 3.1, indicating that workers assessed that they slept 'average' during these naps. ($SD \pm 0.8$ points).

Additional subjective information was also reported. Night shift workers found achieving sleep more difficult after 11:00, due to significantly higher temperatures. Workers also reported that their children caused significant sleep disturbance. Further, night shift workers struggled to avoid social activities when trying to sleep. This was particularly the case in the mornings when workers were arriving home from work and visitors arrived or were present.

Assessment of work hours

As detailed in the methods section, a variety of shift rosters were analysed within Study 3 and Study 4. These were analysed using the FAID bio-mathematical model, which predicts the impact of hours of work on fatigue. It should be noted that only the planned rosters were generally available, and these are reported on here. There was, however, significant evidence that additional overtime was often worked so these results are likely to underestimate the impact of hours of work to fatigue in many cases.

A selection of results are reported below.

- 6 × day shifts (06:30–15:30) followed by 1 d off; 6 × afternoon shifts (14:30–23:30) followed by 2 d off; and 6 × night shifts (22:30–07:30) followed by 3 d off (Fig. 1).

The day shifts (the first block of six shifts) revealed moderate fatigue scores, peaking in the first two hours due to the 06:30 shift start time. Afternoon shifts (the middle block of six shifts) produced low scores, as the time of day had little impact on 'normal' sleep times. Night shifts (the last block of six shifts) were associated with the highest scores, largely attributable to the work hours aligning with times that individuals would choose to sleep if they were not working.

- 6 × day shifts (06:30–18:30) followed by 1 d off; and 6 × night shifts (18:30–06:30) followed by 1 d off (Fig. 2).

The day shift fatigue plot (including the first block of six shifts) indicated mostly low and moderate scores, with small amounts in the high range in the early hours of the morning on the last three shifts. The night roster

Fatigue Plot

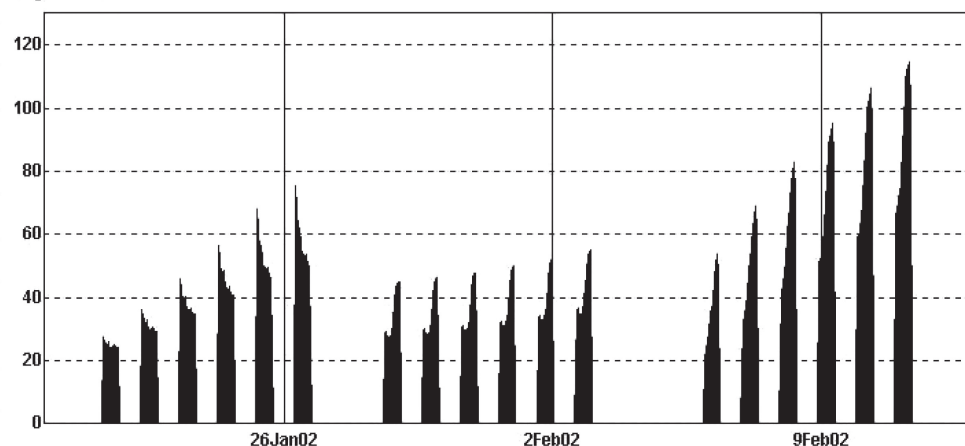


Fig. 1. A FAID Fatigue Plot of a 6 × day shifts (06:30–15:30), 1 d off; 6 × afternoon shifts (14:30–23:30), 2 d off; and 6 × night shifts (22:30–07:30), 3 d off roster.

Please contact the author for more information about the FAID tool, and its application to predict fatigue related to hours of work.

Fatigue Plot

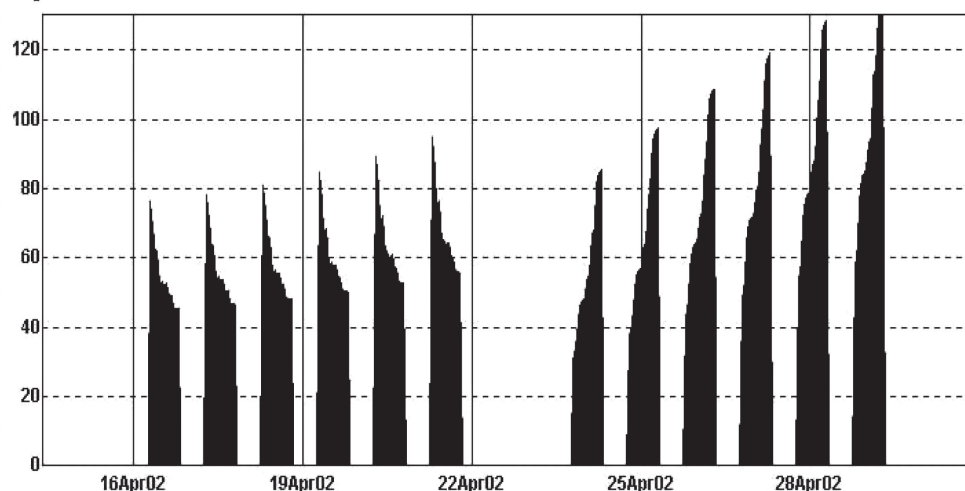


Fig. 2. A FAID Fatigue Plot of a 6 × day shifts (06:30–18:30), 1 d off; and 6 × night shifts (18:30–06:30), 1 d off roster.

Please contact the author for more information about the FAID tool, and its application to predict fatigue related to hours of work.

(the second block of six shifts) revealed levels of high scores, particularly in the last two shifts. The final hours of the second and third night shifts were high and even higher for later hours of the fifth and sixth shifts. Scores suggested that workers were likely to experience difficulty staying awake over the final hours of the last shifts, probably risking their overall safety.

- 4 × day shifts (07:00–19:00) followed by 1 d off; and 4 × night shifts (19:00–07:00) followed by 1 d off (Fig. 3).

Day shift scores were within the moderate range, as can be observed in the first block of four shifts. The

highest scores again occurred early in the shift. Most night shifts revealed moderate fatigue scores, as shown in the last four shifts, with only the last hour of the first night shift and the final hours of the second to fourth night shifts producing 'high' results. The last 1–2 h of the final two shifts were associated with the highest scores.

Minimum requirements for mining camp facilities

Getting recovery sleep between shifts is critical in order to better ensure workers are fit for duty and not significantly impacted by fatigue at work. When work-

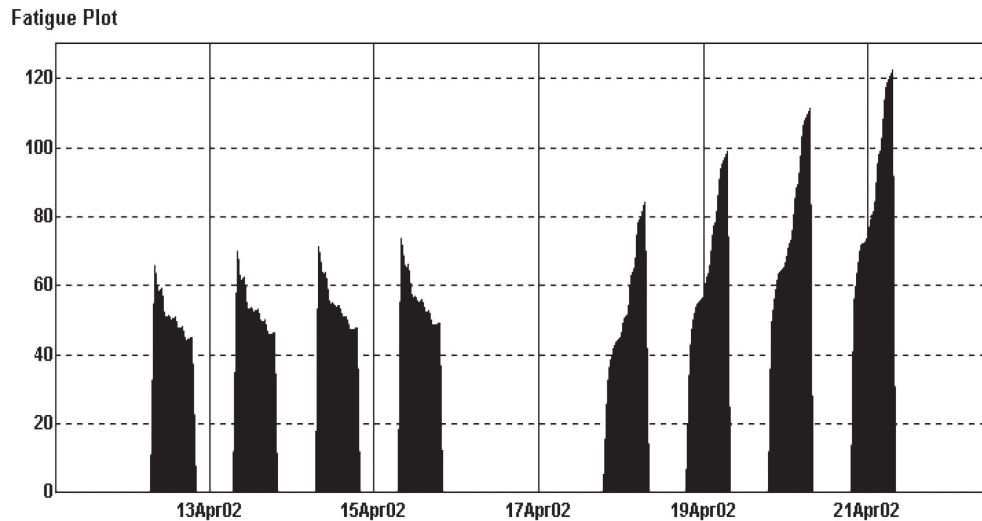


Fig. 3. A FAID Fatigue Plot of a 4 × day shifts (07:00–19:00), 1 d off; and 4 × night shifts (19:00–07:00), 1 d off roster.

Please contact the author for more information about the FAID tool, and its application to predict fatigue related to hours of work.

ers are housed in company camps there is a much higher amount of control available to get higher standards of facilities to help improve likelihood of both quality and quantity sleep. Such standards are very difficult, or impossible to impose, when workers travel back to local villages between shifts. The following minimum requirements are therefore intended for use in remote mining company camps, although the principles can also be applied in homes within villages. The minimum requirements might seem basic from Western standards but they are significantly better than many of the remote mining camps visited in the 5 studies reported on in this paper.

For each worker:

- A clean mattress, pillow, sheet set, and (where necessary) a mosquito net;
- A bed, and sufficient fans to ensure a high volume of air movement (note: where they are available, air-conditioners are to be used in addition to fans);
- Easy access to isotonic/rehydration drinks and water at all times when working in hot environments; and
- Access to snacks, particularly for use during night shifts, to better ensure energy levels are kept stable across shifts.

For the camp:

- Maximum of 6 people per room, with a preferred number being 2–4 per room;
- Sealed walls, ceiling and floors, as well as good waterproofing of the ceiling;
- Reasonable insulation of sleeping areas to limit the effects of noise and light on sleep, while also ensuring good ventilation when it is needed;

- Isolation of all noisy parts of the camp (e.g., the camp kitchen, recreation/televisions areas) away from sleeping areas;
- A ‘suggestion’ box that is cleared at least every week, and a local policy to report back at tool-box talks what ideas have been raised and what will be done about those that are considered reasonable.

Discussion

During the five projects reported on in this paper, there was a wide range of observations made of how sleep and fatigue are managed by companies (including contractors) in Kalimantan, Indonesia. Certain aspects of existing systems are valuable while others need to be vastly improved²¹). This is true of behaviours and processes observed directly as well as procedures and processes investigated in documentation of the organisations. Like any effective safety management system, fatigue management is likely to reduce incidents and accidents most when there are numerous layers to the system. That is, that there are numerous overlapping controls in place to manage fatigue, including the management of key factors such as:

- The length and timing of work, including overtime;
- The work environment in terms of heat, humidity, time pressures, boredom, access to task rotations, level of communication with other workers and supervisors;
- Availability and use of breaks within shifts, especially at times when it is likely that individuals will feel more sleepy and less able to concentrate for

long periods of time;

- The interaction of fatigue-related risks with other identified risks such as safety-critical maintenance, shut-downs, emergency operations or others involving long hours of work, working at heights, etc.; and
- Individual differences, which requires systems that train people to communicate with other workers and/or supervisors when they are unsafe to continue working due to a likely fatigue-related event such as falling asleep while driving.

Perhaps the biggest overall requirement of company systems is the extension of risk management to include fatigue-related risks. The vast majority of mining companies have mature risk management cultures and there is no major difficulty –from a skills or culture perspective– as to why formal risk management processes are not used to identify, assess, control, document, monitor and review fatigue-related risks. This should be done as a priority in all companies where it is not already mature.

In parallel with the initial identification and assessment of fatigue-related risks, companies should be developing or expanding the fatigue aspects of their fitness-for-duty, safety management and auditing activities. This is because until fatigue management is a part of the policy, procedures and method of operation on a day-to-day basis, the benefits of better management will be poor or non-existent, and probably short-term in nature. As discussed in this paper, there are many basic elements in an effective fatigue-management system – which all need to be integrated together– and these include:

- Policy, procedures, and guidelines;
- Accident and incident reporting questions, and additions to the investigation requirements;
- Hours of work monitoring so that all planned and actual hours of work are accurately recorded and assessed periodically (for evidence of high work hours being associated with accidents and incidents, or other unsustainable practices);
- Training and education for all relevant levels of worker, supervisor, manager, contractor, auditor and investigator;
- Reporting systems that allow fatigue to be a legitimate item in hazard registers, near-miss reports, as well as self- and peer-report systems; and
- Auditing frameworks to make verification audits that key information is being collected, concerning trends or risks are being identified and actioned, and system reviews and improvements are being completed.

While all of these things might be considered fairly

routine, or at least somewhat familiar, in a multi-national mining company senior management group, they are quite foreign at the level of a local operation that is remote in the jungles of Borneo. Therefore, as part of the development and implementation of fatigue-related risk management systems in remote mining projects it is not only important to collect data and consider the local context –as was done in the studies reported in this paper– but it is also necessary to increase the relevant skills and knowledge of the local workforce. It is likely that it will take at least a 2-yr period to build capacity of local workers, supervisors and managers, but from that time onwards it is reasonable to expect the main activities of the corporate areas of any company to be mainly support, resourcing, monitoring and auditing. Without the development of understanding, skills and knowledge at a local level it is unlikely that any sustainable benefits can be gained.

In addition to the development –including collection of appropriate information and tailoring to the local context– of a risk-based fatigue management system, there are also some other basic requirements. The most important of these found was alignment with local cultures, such as providing leave for family death ceremonies or burials in Kalimantan (with flexibility kept for operations to the degree it is reasonable).

In conclusion, the interaction of cultures, stress, sleep, fatigue, safety and individual differences must be more effectively addressed in remote mining camps. The risk-based management of fatigue and related interactions occurs both within companies and the communities that support them. This is especially true in remote communities such as those involved in the studies reported in this paper. Long-term improvement of issues can therefore only occur by addressing the underlying causes at both the company and community levels. With senior management commitment and resourcing, as well as with the development of understanding and solutions at a local level, much better safety and more sustainable methods of operation can be developed and implemented. In time, this will lead to better lives for the workers, better results and productivity for the company, and greater support from the local communities.

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