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Fatigue Risk Management

GUIDELINE



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Guideline Change Procedures

The RISSB maintains the master for this document and publishes the current version on the RISSB website.

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Abbreviations

DIDO – Drive in/Drive out working arrangement
FIFO – Fly-in/Fly-out working arrangement
FRMP – Fatigue Risk Management Program
ISO 31000 – AS/NZS ISO 31000:2009 Risk Management – Principles and guidelines
RSSB – Rail Safety and Standards Board, UK
RTO – Rail Transport Operator
SMS – Safety Management System
WHS – Work Health and Safety

Definitions:

Fatigue-related risk – the multiplication of the likelihood of fatigue (impairment or reduced alertness) and the consequence of fatigue (outcome of a fatigue-related error or violation) in a given situation, including any existing and additional controls.

Rail Safety Worker – A worker who has carried out, is carrying out or is about to carry out rail safety work *as defined by rail safety legislation* (see Rail Safety National Law - section 8). For the purpose of this document, the definition includes a direct employee, contractor, subcontractor, volunteer or other person engaged by the rail transport operator to perform work in relation to a railway or tramway system.

So Far As Is Reasonably Practicable (SFAIRP) – Please refer to NTC Guideline for SFAIRP for a description. Please note that at time of writing, the National Rail Safety Regulator is producing SFAIRP guidance, which will supersede the NTC Guideline**.**

Good Practice - is anything (including policy, standards, procedures, actions, designs or equipment) which, when implemented or used, produces a cost effective outcome that is (within the SFAIRP context) Safe; Efficient; Effective; Accessible; Equitable; Environmentally sound; Legally defensible, and Innovative.

Preamble:

The Australian Rail industry is committed to the safety of its operations in respect to employees, passengers and the community. Given the advances in our understanding about the science of fatigue and performance, the industry is focused on ensuring it is managing the risk using evidence-based good practice.

The guideline draws on a number of other good practice documents and academic pieces and RISSB would like to acknowledge:

- WorkSafe Victoria
- NSW Mines Safety Advisory Council
- Rail Safety Standards Board United Kingdom (RSSB UK)
- Independent Transport Safety Regulator NSW (ITSR)
- Office of Rail Regulator UK
- BHP Billiton
- CQUniversity

1 Introduction

1.1 Purpose of guideline

The guideline provides non-mandatory guidance to rail organisations on good practice fatigue risk management for rail safety workers. The guideline will be in line with the new National Rail Safety Law and other relevant documentation detailing good practice in this area.

The guideline will be updated as required as future research and information becomes available.

1.2 Target audience

The target audience for the guideline is Australian rail transport operators who have responsibility for developing, implementing and managing FRMP.

1.3 Legislation and Regulations

Rail Transport Operators must regularly review their Safety Management Systems for compliance with all relevant regulations.

The *Rail Safety National Law and Regulations* specify the requirements of rail operators in regards to managing fatigue-related risk. Specifically rail transport operators are required to:

Ensure, so far as is reasonably practicable that rail safety workers who perform rail safety work in relation to the operator's railway operations do not carry out rail safety work while impaired by fatigue or if they may become so impaired (s52(2)(d));

Prepare and implement a program, in accordance with the prescribed requirements, for the management of fatigue of rail safety workers who carry out work in relation to railway operations in respect of which the operator is required to be accredited (s116);

Regulation 29 of the Rail Safety National Law provides further detail around the factors that must be considered in the development of a fatigue risk management program (represented in Figure 2).

In addition to the above, there are notification requirements in the law:

A rail transport operator must notify the Regulator in writing of a proposed decision to change any work scheduling practices and procedures set out in the operator's fatigue risk management program at least 28 days before the date the operator intends to bring the change into effect (refer to regulation 9(1)(a) (Prescribed conditions and restrictions) of the National Regulations).

The operator must give the Regulator a written report of any breach of the work scheduling practices and procedures set out in the operator's fatigue risk management program within 72 hours after becoming aware of the occurrence (refer to regulation 40(b)(xv) (Reporting of notifiable occurrences) of the National Regulations).

Consideration should also be given to: WHS Laws in relevant jurisdictions; industrial laws and agreements; other relevant pieces of legislation (e.g. National Heavy Vehicle Regulations).

1.4 How to use this guideline

This guideline is relevant to all rail transport operators in Australia, irrespective of the work schedules or type of work conducted.

Organisations that do not use shiftwork, extended or irregular hours (e.g. Tourist and Heritage) are still required to have a fatigue risk management program in place, which will involve simple fatigue risk identification and control processes.

Organisations carrying elevated risk associated with work schedules (e.g. night work, shiftwork, irregular or extended hours) will require a more comprehensive FRMP involving multiple defences and controls to manage the risk.

The guideline outlines the key components of a FRMP, and the processes required to implement and maintain a FRMP. It can be used by all organisations, irrespective of the risk level and will allow the risk management processes to be proportional to the degree of risk.

Good practice fatigue risk management

The document provides guidance in relation to good practice fatigue risk management as well as evidence-based rostering considerations.

Rostering within a set of evidence-based work hours dimensions that are associated with low likelihood of work-related fatigue still requires that the fatigue-related risk be assessed in relation to the work context. But organisations using rostering dimensions associated with low likelihood of fatigue based on the evidence, may need fewer additional fatigue risk management controls.

Fatigue risk management requires that operators consider information about evidence-based rostering, assess the risk associated with the specific work context and implement additional appropriate controls. For example, if operations involve night work, extended or irregular hours and the risks of the tasks are high, then higher level controls may be required.

1.5 Fatigue in the rail industry

Fatigue is a hazard in all industries that use ‘non-standard’ hours (e.g. shiftwork, extended hours, night work, on-call work etc) and rail is no exception. The diversity in working time arrangements and operational environments in the Australian rail industry means that management of fatigue-related risk should be tailored to the unique risks and context of the particular rail operations. The range of diverse work practices (schedules, environments, operations, services provided) means that a one-size-fits all approach to fatigue risk management is not appropriate.

In a system that relies heavily on human performance, fatigue can be quite costly. Consequences of fatigue for the organisation may include increased risk of incidents/accidents (and associated insurance implications), decreased productivity and efficiency, higher absenteeism and reduced morale. On the other hand, the benefits of fatigue management for organisations extend to worker health and well-being, safer work environment, enhanced performance, reduced absenteeism, productivity gains and commercial advantages (see A.5).

2 Background

2.1 What is fatigue? (A.2)

In general, fatigue can be defined as feelings of tiredness and reduced ability to perform mental and physical tasks. Fatigue manifests in impaired performance, reduced alertness, and reduced capacity to concentrate, coordinate tasks, respond to certain situations and recognise risk. Fatigue arises as a result of inadequate sleep, time of day, workload and work task.

2.2 Causal factors (A.3)

The systems controlling sleep and biological rhythms are physiologically similar in all human beings. Thus, the factors that cause fatigue act in very similar ways in all of us:

- inadequate sleep
- extended periods of wakefulness
- time of day (circadian) factors

The **likelihood** of fatigue is also influenced by:

- work tasks
- environmental factors
- health status

The causes listed above can arise as a result of both work- and non-work-related factors.

2.2.1 Work-related factors

Key work-related factors that increase the likelihood of fatigue are listed below, together with some information about the impact of each on biological causes of fatigue. (The background literature supporting the following examples is provided in Appendix A – specific sections are noted).

- Night work - reduces the opportunity for sleep at the 'optimal' time. Night work also requires people to work at the 'least optimal' time for performance and alertness. (A.3.1)
- Longer shifts - the likelihood of fatigue increases beyond 8 hours as a result of extended wake and workload. (A.3.3)
- Early start times (e.g. before 0600) - can result in shortened sleep periods as the biological drive to stay awake in the evening hours means that it is difficult to compensate for an early morning start. Early starts also require workers to be operating during the circadian low point for performance and alertness. (A.3.1)
- Consecutive shifts - result in sleep debt building up over a block of shifts (night shifts or early starts in particular). (A.3.2)
- Inadequate break periods between shifts - limit the amount of time for good quality restorative sleep. (A.3.2)
- Time on task - increases the risk of fatigue, whether it be a mentally or physically demanding tasks. (A.3.3, A.3.4)
- Unplanned hours (short notice work) - reduces the chance of an individual planning ahead for sleep. (A.3.2)
- Commuting – long commutes reduce the time available for sleep between work shifts and extend wakefulness. The commute may be particularly long in some FIFO or DIDO

operations. If the commute is a long one then an early start may be required even if the scheduled work start is after 0600. If self-driving the commute may add to the workload across the shift. (A.3.3)

- Workload - both high and low cognitive workload can influence fatigue and impairment. (A.3.4)
- Occupational stressors – psychological stress can impact sleep. (A.3.5)
- Environmental factors – for example heat, humidity, noise and vibration can all exacerbate symptoms of fatigue. (A.3.2.1)
- Shiftwork-related health problems (A.3.5)

Table 2 provides information about how each of the sub-clauses of Regulation 29 map onto the causes of fatigue.

It is also important to note that although the factors listed above are known to cause increased levels of fatigue, they should be reviewed within the context of a safe system of work.

2.2.2 Non work-related factors

Non work-related factors can also increase the likelihood of fatigue by reducing the opportunities for sleep, rest and recovery.

- Domestic or social factors – long hours mean that people may not have enough time to do everything they want or need to and sometimes sleep is sacrificed for domestic, social or leisure activities. In some cases, sleep is not prioritized, despite sufficient time away from work. In other cases, despite every effort, sleep is not obtained. (A.3.5)
- Health status – some medical disorders impact the quality and quantity of sleep that people obtain. Sleep apnea is a disorder known to affect sleep and is associated with excessive daytime sleepiness and impaired waking performance. Chronic pain may also disrupt sleep, as may various forms of insomnia and other chronic disease such as diabetes. (A.3.5)
- Sleep environment and sleep hygiene – the environment in which one sleeps impacts sleep quality and quantity. Poor sleep hygiene (lack of a bedtime routine, televisions, computers and phones in the bedroom, drinking alcohol and caffeine close to bed time etc) can affect sleep. Comfort, minimising light, noise and high temperatures are all important for good sleep. (A.3.2)
- Individual factors – there is a degree of individual variability in relation to how much sleep people get and need. Factors such as age, life stage, stress and underlying physiology can impact sleep timing, sleep quality and sleep quantity. (A.3.5)
- Lifestyle/diet – there is some interaction between lifestyle and diet and sleep. Sleep is good for health and healthy people generally sleep better. (A.3.5)
- Secondary or volunteer work – having more than one job will put extra pressure on the time available for sleep and may result in an individual not being rested or fit for duty for either job.

2.3 Consequences of fatigue (A.4)

In the same way that inadequate sleep and circadian disruption impact fatigue universally, the human consequences of fatigue are also essentially universal. Understanding the effects of fatigue helps to assess the risk for a given work task or worker.

Mental and physical performance are both impaired by fatigue. Inadequate sleep, extended wake and time of day all impact how well individuals perform physical and cognitive tasks and

the way they interact with team-mates and their environment. One of the most obvious consequences of fatigue is sleepiness. This can range from mild levels of tiredness (e.g. yawning) through to uncontrolled sleep (e.g. microsleeps). Changes to waking performance can include:

- Decision-making – judgment and decision-making abilities are impaired by fatigue. Individuals take more risks and are less accurate at rating their own performance. It is more difficult to process complex information and to keep track of multiple pieces of information when one is fatigued.
- Physical performance - hand-eye coordination, reaction time, physical strength and coordination are all impacted to varying degrees by fatigue.
- Mental performance – vigilance, concentration, the ability to stay focused, the ability to respond to signals/stimuli in the environment, situational awareness and communication are all impacted by fatigue.
- Mood – at higher levels of fatigue, people become more withdrawn, more irritable and less communicative. This has particular repercussions for team-based work.

From the perspective of health outcomes, there is evidence of a higher rate of some illness in shiftworkers, including gastrointestinal illness, cardiovascular disease, impaired immune function and some cancers.

3 Fatigue Risk Management Overview

Understanding the causes and consequences of fatigue in the workplace provides opportunity for managing the risk of fatigue-related accidents. The goals of fatigue risk management are to reduce the likelihood of elevated fatigue levels and mitigate the risks where fatigue levels are elevated.

As with any other health and safety risk, all rail operators need to manage the risks related to fatigue. Organisations that use extended hours or shiftwork in their operations are likely to require a higher level of control to manage the higher risk. Further, risk assessments must also take into account the context in which the work occurs. Hours of work can provide information about the likelihood of impairment in performance or alertness, and may also be used as controls or risk treatments. However, hours of work limits are not enough by themselves to manage fatigue-related risk.

Outside the Box
As with any risk management process, the ideal situation is to remove the hazard completely. Operators should, using a risk management approach, examine whether it is possible to eliminate the hazard. Is night work necessary? Are extended hours essential? Can we do this work differently to eliminate the source of fatigue? These are questions worth asking but it is acknowledged that for some operations, the hazard cannot be eliminated.

An integrated risk management program is one that incorporates management practices, ideals and procedures in monitoring and managing all aspects of risk to the health and safety of employees. A safety management system approach to fatigue involves multiple strategies to manage fatigue-related risk. In the context of this multidimensional approach, a fatigue risk management system can be defined as '*a scientifically based and flexible alternative to rigid work time limitations, that provides a layered system of defences to minimise, as far as is reasonable practicable, the adverse effects of fatigue on workforce alertness and performance, and the safety risk that this represents'* (see A.5).

Things to consider in relation to fatigue risk management:

Risk management requires the institution of tailored controls that manage the risk so far as is as reasonably practicable. Where the likelihood of impairment due to fatigue is high, and there are consequences for health and safety, additional controls are required.

Case Study 1
The establishment of temporary sign on/sign off locations (typically during grain haulage peaks) for train crew often results in self-drive of motor vehicles before and after normal shifts. A fatigue risk assessment examines the likelihood and consequences of a fatigue-related impairment during the drive. Fatigue risk is determined to be higher during haulage periods and thus additional tailored controls are identified and implemented for the duration of the peak period (e.g. temporary resting arrangements).

Risk management is not a proxy for risk justification. Fatigue risk management should not be used simply to justify longer working hours. However, where risk is managed appropriately,

non-standard hours may be preferable.

Case Study 2
A new mine in a remote area requires a rail service to a coastal port. The distance and the existing rail infrastructure would require trains to be scheduled for a 56-hour round trip, including loading and unloading. There is an existing intermediate depot, but it has been difficult to maintain staff at that location. A meeting of stakeholders, including train crew, discusses the options of using the existing depots, or using relay working. Risk assessments are carried out and determine that the relay options has the lowest risk due to its shorter duty shifts, not commuting during work shifts, and better home (coastal) depot location. However, the risk of fatigue due to the long work duty cycles (across trips) was also considered to be high.

The following controls were agreed:

- Four driver working configuration – two driving, two resting
- High quality resting crew vans, with maximum noise attenuation, individual air-conditioning units in bedrooms, passenger ride quality design principles
- Maximum shift/drive times of 8 hours, unless otherwise agreed by the team so as to maximize night sleep
- Rostered time off to equal rostered time on, with a minimum of 36 hours off between trips
- Local 8-hour shifts to be used for the unloading process

A working time arrangement should meet a number of needs – domestic, financial, fatigue and social. Fatigue management should not be the only factor that drives the development and review of any rostering or work hours arrangements.

Case Study 3
Shift swapping is a common occurrence in an organisation and a new senior manager decides that the practice is stopped and all rosters be worked as originally planned. The supervisors request that the decision be reviewed, and present information about the types of swaps that are permissible within a set of local ‘hours of work guidelines’ previously developed by the group using a risk assessment process. The supervisors also provided evidence that the practice was not increasing risk, that the rostering personnel understand the implications of shift swaps and are trained in fatigue management, and that workers are more satisfied when they are allowed to make requests for shift swaps. The reasons given included family, social and personal and the changes allowed them, where appropriate, to fit work in with their lives.

Managing fatigue-related risk in a workplace is a shared responsibility. Both work and non-work factors can lead to increased fatigue-related risk in the workplace or on the drive to/from the workplace. A comprehensive FRMP should have systems in place that support the reporting of fatigue and to detect instances of increased fatigue-related risk as they arise.

Case Study 4
A guard begins a day shift feeling well rested and alert. After lunch, she starts feeling a little drowsy and goes outside for some fresh air. She had eight hours in bed but felt like her sleep was a bit more disturbed than usual. When she finds herself having trouble concentrating on the radio she contacts her supervisor to let her know. Together they determine that the guard is somewhat impaired and there is an increased chance of her making an error or missing something. They plan a short break and a reassessment in 30 minutes, after which the guard returns to work feeling alert. The organisations's fatigue management policy encourages self-reporting and includes a procedure for managing recurring issues.

The design of the FRMP will be dictated by the risk context. Different risks and risk management processes may apply both within an organisation and between organisations involved in railway operations (e.g. urban rail systems vs long haul freight vs tourist and heritage vs maintenance vs construction).

Case Study 5
A signaling or track fault has disrupted train services and a crew is approaching 10 hours on duty. Relief is not readily available and the disruption is expected to be short, with the probability this crew can complete their shift within 12-13 hours. A risk assessment of the circumstances provides for the train pulling into a siding for the crew to have a rest. A further risk assessment will be undertaken on resumption of services including the crew assessing their ability to continue. If any crew members are to nap during the rest opportunity, consideration should be given to ensuring the train is secure, whether it is appropriate to have one member of the team awake during the rest opportunity, and ensuring that following a nap adequate time is taken to alleviate any effects of sleep inertia on alertness and performance upon restarting work (see Napping below).

Investigating fatigue-related incidents is a critical component of the system (see Appendix B).

Case Study 6
A grinding crew is returning from a day shift to the depot. Twenty minutes out from the depot, their vehicle leaves the road and ends up in a ditch on the edge of the road, written off. All occupants are unharmed. The incident investigation team asks questions about the driver's hours of work in the last seven days, the total hours of sleep in the last 48 hours and the quality of the sleep, any signs of fatigue preceding the accident, the characteristics of the accident (swerving, animals on the road, mechanical issues), how the driver felt prior to the crash. The information from the investigation is used to review current fatigue risk management procedures and develop additional controls where deemed appropriate and practicable.

All steps in the risk management process need to be documented by the organisation, for example, as per ISO 31000.

Case Study 7
Investigation into an incident causing serious injury to a worker determined it was fatigue related. Furthermore, the task had been subject to an earlier risk assessment that had recommended fatigue management controls that might have prevented the most recent incident. However, the risk assessment was informal, in the form of a job safety analysis, and although its outcomes were implemented in the short term, it had not been properly documented. No actions or responsibilities were assigned in relation to the findings and hence the controls had not been put in place. Workers had reverted to previous practice over time. The lack of appropriate controls to manage the fatigue-related risk was found to be the main contributing factor to the incident.

There is a requirement to integrate the FRMP into the broader Safety Management System, and should cross reference policies such as Risk Management, Human Factors, Drug and Alcohol Management and Heath Assessments.

Napping – see also A.5
Napping has been shown to provide measureable improvements in alertness and performance of fatigued individuals.

- Naps can be taken in short durations (e.g. 20 – 30 minutes before driving home), or longer (e.g. an hour or more in preparation for a night shift).
- Sleep inertia following a nap can be a concern. Sleep inertia is the slow, disoriented or hazy feeling after waking up from a sleep or a nap and is worse when: Woken up by someone else or an alarm as opposed to waking up naturally; Having a nap at a time of day that would normally be used for sleeping (e.g. naps that are taken between midnight and 0600); or woken from a very deep stage of sleep. A 20 minute nap will generally not be associated with a deep stage of sleep. Longer naps, around 45 minutes or more, are more likely to include deep sleep, from which it takes longer to wake.
- At least 20 minutes is suggested as necessary for waking up before performing safety critical duties. This time should be taken by walking around in a well it area – its an ideal time for a cup of coffee!

Further, organisations are encouraged to develop educational material and procedures related to napping. Napping may not be appropriate for all settings.

4 Key elements of the FRMP

The key elements of a Fatigue Risk Management Program are shown in Figure 1. Generic risk management components include Policy, Roles and Responsibilities, Knowledge and Training, Communication and Consultation and Audit. The following section provides detail about the key components of a FRMP (see also checklist at the end of Section 5).

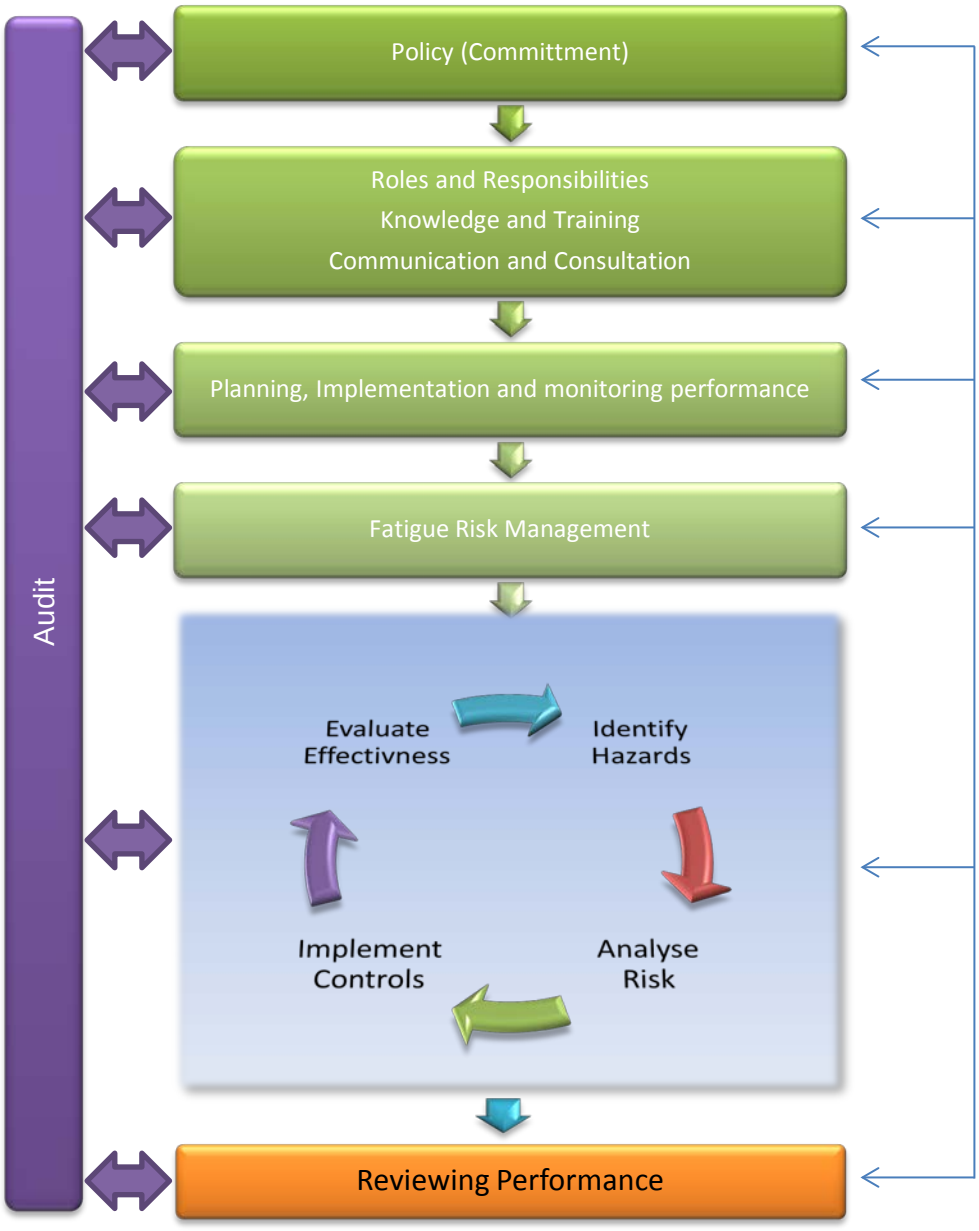


Figure 1 – Components of a Fatigue Risk Management Program (drawing from the ISO 31000 standard and RSSB, UK Guideline).

4.1 Policy

A fatigue management policy is a statement of the organisation's ongoing commitment to the management of fatigue-related risk. The commitment should be visible in the actions of senior

management. The FRMP should be integrated into the organisation's Safety Management System and cross-reference other relevant human factor policies.

The policy should be developed by management, using a participative approach with all stakeholders and be informed by the fatigue risk assessment process.

The policy should specify frequency of review to ensure it remains current, reflects changes in working arrangements and includes new methods of managing fatigue (external advice may be sought on developments in fatigue management).

The policy should be supported by a procedure or other guidance material. Such documents may include:

- Roles and responsibilities for managing fatigue-related risk.
- A commitment to allocate the necessary resources.
- Demonstration of an understanding of fatigue and its impacts.
- The process for assessing the risks and hazards in developing a fatigue risk management system.
- Key principles guiding roster design.
- Requirements for minimising the risk arising from contingencies and emergency circumstances where the limits set in the FRMP may need to be exceeded.
- A just culture policy to support self-reporting of fatigue issues and occurrence investigation.
- Training and education processes.

4.2 Roles and Responsibilities

The responsibility for managing fatigue-related risk in the workplace is shared between employer and employee. For example the organisation should develop and implement a fatigue risk management program that includes the implementation of control measures and any materials that may assist or be needed for implementation and awareness programs that help individuals to understand their responsibility to report fit for duty (Table 1).

Table 1 – Roles and Responsibilities

Role	Responsibility
Board	Responsible for the Corporate Governance and oversight of the organisation
CEO	Responsible for the organisation's Safety Management System, which includes fatigue risk management. Support positive culture within the company with regard to fatigue management. Initiate development of FRMP including all relevant documentation
Senior Management and Executive	Development and implementation of the fatigue risk management program, including policies and procedures. Ongoing review and modification of fatigue risk management program
Line Managers Supervisors	Manage fatigue-related risk within local area using systems and procedures Arrange for training, follow-up and investigate local fatigue-related incidents and exceedances Assist in the management of individual fatigue risk management within their local area Ensure personnel responsible for preparing rosters have appropriate knowledge and skills to design rosters in line with the principles outlined in the FRMP
Rail Safety Workers	Participate in the development, implementation and activities of the FRMP. Report fit for duty Complete any FRMP training Report fatigue

4.3 Knowledge and Training

Fatigue training is a fundamental part of any effective FRMP. The level of training that employees receive should correspond with the hours that they work and the nature of the tasks they are required to carry out.

The content and form of training may differ within and between rail transport operators depending on their risk context.

Fatigue management training programs may include:

- Guidance in identifying the effects of fatigue and the impact on health and safety
- Information about the organisation's fatigue management policy and procedures;
- Participation in the risk assessment process and the development of fatigue risk management program, and changes to working arrangements;
- Information and guidance about using rest and recovery opportunities between shifts;
- Identification and implementation of control strategies for minimising fatigue-related risk at work;
- Information about the effects of fatigue on task performance including the signs and symptoms, the types of errors and violations that arise from fatigue and how to better detect and manage them in themselves and others (e.g. non-technical skills, rail resource management or threat and error management) (see also Checklist in Appendix D);
- Information about sleep hygiene, sleep disorders, fatigue reporting;
- Information on latest amendments to rules, regulations and legislation related to fatigue management.

Training is particularly important for workers directly involved in the management of rail safety workers and/or preparation or implementation of shift rosters. Such training would focus on the organisation's rostering principles, the ways in which tools are to be used in the processes, and the strengths and weaknesses of such tools.

Provide appropriate information to management and other workers not directly involved in rail safety work as they too, in the course of their employment, may be at risk or making decisions affecting people at risk.

Organisations may develop and maintain an education program that includes a knowledge based training program for rail safety workers, that is aligned with the Australian Qualifications Framework TLIF 2010A (Apply Fatigue Management Strategies). The training may utilise current curricula as defined by the Department of Education, Science and Training (DEST). Competency based training may also be made available providing nationally recognised Certificates of Attainment.

4.4 Communication and Consultation

The Rail Safety National Law stipulates that consultation with affected persons (being persons who carry out those railway operations, work on or at the operator's railway premises or with the operator's rolling stock), their health and safety or union representatives, and the public (as appropriate) is required. "Communication and consultation" is aimed at increasing participation by stakeholders, improving the quality of information that is fed into the fatigue risk management program and increasing the participation of all stakeholders.

The greatest benefits of communication and consultation are likely to occur:

- During development of the FRMP
- When the organisation identifies fatigue is a hazard in the workplace
- During the monitoring and review of an organization's existing fatigue management program
- When changes are proposed to work schedules and working procedures
- At the time new work schedules and working procedures are introduced
- During the development of the risk management approach
- When there are ongoing signs of fatigue affecting the health and safety of workers,
- After an incident (or 'near miss') occurs.

5 Fatigue Risk Management Process

5.1 Overview

The Risk Management process involves four main phases as shown in Figure 1. It is important to note that fatigue risk management is more than just hours of work. While hours of work represent one of the sources of fatigue-related risk, the context in which the work occurs is also important.

Risk management may allow an organisation to take advantage of opportunities that might not otherwise be available. In relation to fatigue-related risk, the benefits may include improved productivity and efficiency, reduced costs related to safety and incidents and organisational reputation. However, it should be emphasized that a risk management approach does not justify work hours or working arrangements that place organizational objectives above health, safety and well-being.

The objectives of the organisation, group or project should be made explicit. These may include:

- Deliver services safely
- Achieve project goals
- Review working time arrangements for a given group or operation

The context in which the fatigue risk assessment is being conducted is also important and may include external factors, internal factors and the organisation's risk management processes.

External context: (includes, but not limited to) stakeholders, regulations/legislation and other relevant documents, social and cultural factors, environmental considerations.

Internal context: (includes, but not limited to) governance, organizational culture, safety culture, policies and objectives, safety management system, shiftwork/extended hours, employees and their tasks.

Risk management: why and how the risk management process is being undertaken, roles and responsibilities for fatigue risk management, definitions of success, scope of the work.

5.2 Identifying hazards

Risk management involves identifying sources of risk, how they impact, their causes and potential consequences (ISO 31000-2009). The first step in managing fatigue-related risk is to use a systematic approach to the identification of all sources of fatigue-related risk for rail safety workers, or a given operation or project. Rail safety workers and/or their nominated representatives should be part of this process. Sources of risk can be identified through:

- Assessment of roster/work hours;
- Incident investigation reports;
- Analysis of errors and violations;
- Fatigue reporting systems;
- Site inspections;
- Discussions with rail safety workers and/or their representatives which may include surveys or questionnaires;
- Audit results;

- Evidence based research about fatigue that is reported in scientific or industrial literature;
- Review of working time exceedances (see Section 6.1);
- Analysis of the operational cycle/work task sequences;
- Absenteeism data to identify links with specific working time arrangements;
- Work environment including tasks, scheduling, workloads and environmental factors.

5.2.1 Work Hours and fatigue likelihood

This section provides information about the scientific evidence related to fatigue likelihood and work hours dimensions. The scientific evidence informs the fatigue likelihood assessment, which is one part of the risk equation (2). There are various key dimensions of work hours to consider, as there are various dimensions of the work task to consider.

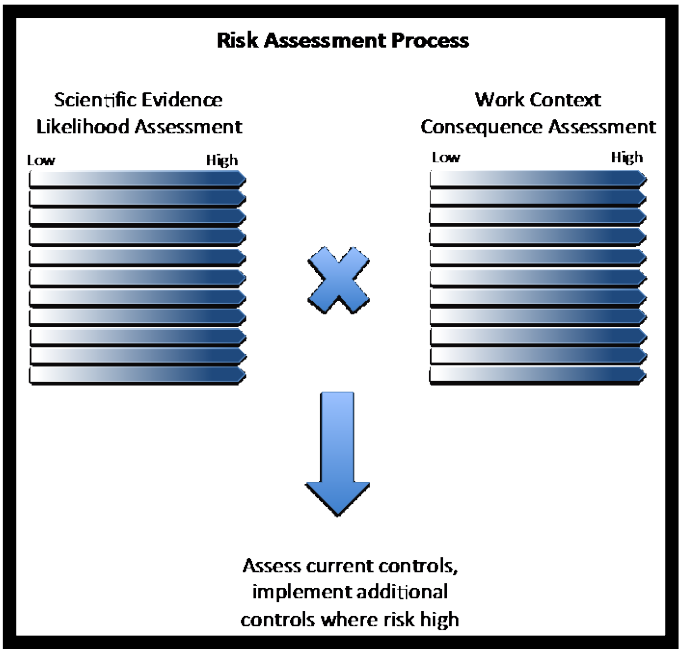


Figure 2 – Risk assessment process involves analysis of likelihood, consequence assessment and current controls to determine risk. Additional controls applied to manage residual risk.

The biology of human sleep and circadian rhythms underlies the changes in fatigue likelihood that occur with longer time awake, different times of day, and over consecutive days/nights for example. The scientific evidence from field and laboratory studies is summarised in the Figure 3.

Figure 3 is not showing risk levels – risk depends on the particular tasks, the operating context in which the work is being done, and assessment of both likelihood and consequence.

The gradient in colour demonstrates the idea there is a continuum of fatigue likelihood in relation to each dimension – there are no distinct/absolute measures for fatigue likelihood.

Work patterns that involve increased likelihood of fatigue are used throughout the industry (and many other industries) in association with appropriate controls. High fatigue likelihood does not necessarily mean work hours are outside the limits. It may mean additional controls are required. These controls may include other work hours dimensions – for example, longer shifts = fewer in the block, or night work = longer time between shifts to maximize sleep opportunity. However, there will be some situations in which the risk is not manageable.

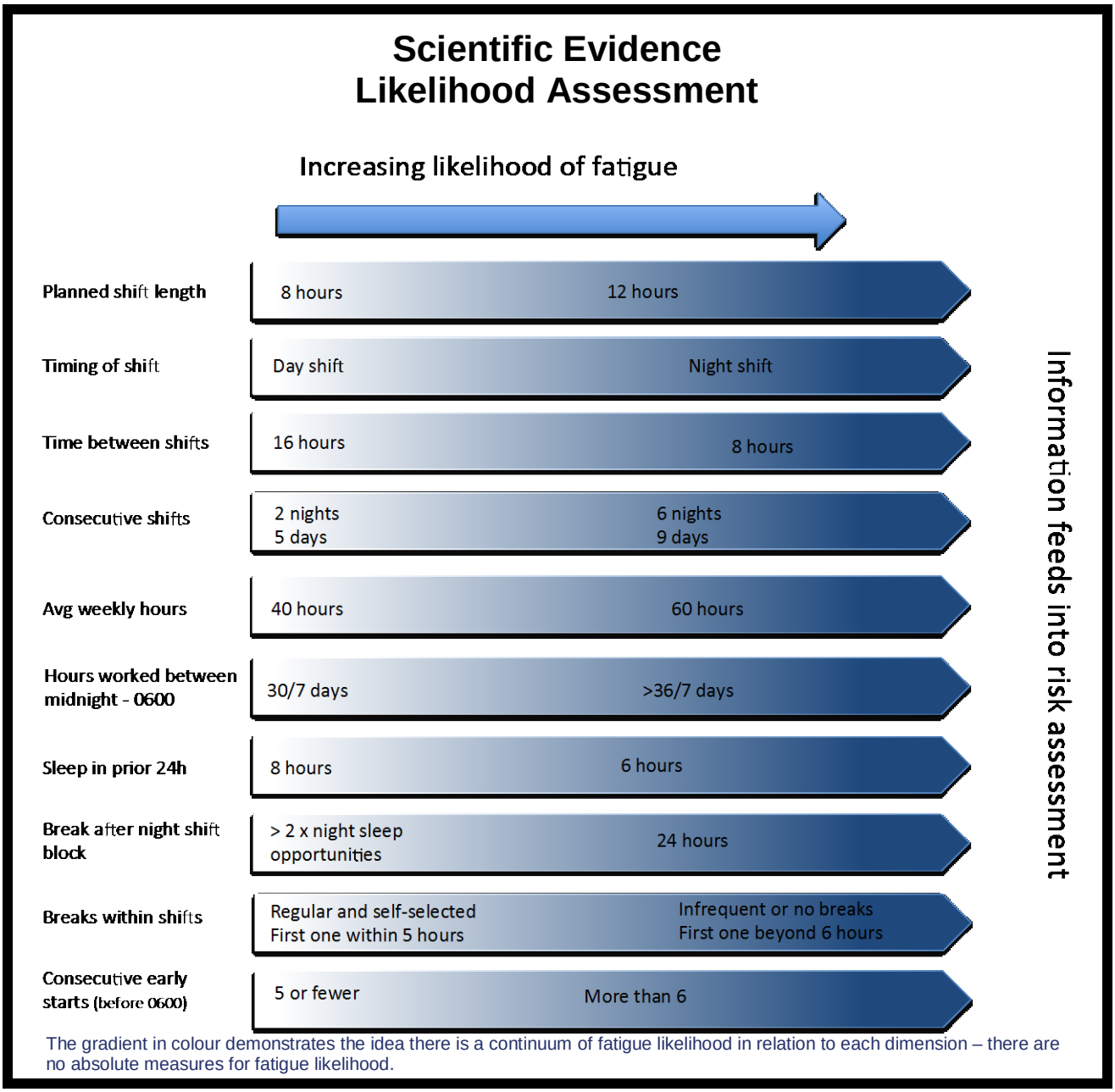


Figure 3 - The information summarised in the matrix can assist operators with their risk assessments – fatigue likelihood associated with the work pattern is only one part of the risk assessment process.

Things to consider:
Work patterns at the low likelihood end of the spectrum provide for significant sleep opportunity during the night hours and don't involve long hours. The other end of the spectrum is associated with longer hours during the night and consecutive shifts.

Hours and Risk
It is difficult to draw lines in the sand around fatigue-related risk. There are no absolute cut-offs beyond which we know definitively that risk is increased. As an example, shift lengths of 8 hours are generally low risk and shifts between 8-10 hours are probably higher risk etc. But the science cannot tell us that while 8 hours is safe, 8 hours and 1 minute is not. Rather, the literature highlights increasing likelihood of impairment, and therefore error, with increasing shift length. While work hours are not the only factor that impacts fatigue, they are an appropriate focus for assessing the degree to which the hazard might result in performance impairment. It is the case that longer hours on the diagram can be worked safely with the appropriate controls (tailored to the work context).

The work hours dimensions interact to affect fatigue likelihood. For example, a 12-hour shift at night will be associated with an increased likelihood of fatigue compared to a 12-hour shift during the day hours, and particularly at certain times of the shift. Further, it is possible that combining several low fatigue hazard dimensions may involve increased fatigue likelihood.

Case Study 8
A new roster is being proposed for regular work between 2000 and 0600, Monday to Friday. A proposal to work five consecutive 10-hour shifts was assessed using information about work hours dimensions and their relationship to fatigue likelihood.
Night shifts – high likelihood
14 hour breaks between shifts – low likelihood
5 consecutive night shifts – moderate likelihood
50 hours/week – moderate likelihood
Night hours (midnight – 0600)/week – moderate likelihood

If the risk assessment, taking account of the work context and proposed hours, determines that the risk cannot be mitigated, then a roster using fewer consecutive shifts and/or shorter shifts with longer breaks between shifts could be considered. Other possible fatigue risk management controls may include breaks within shifts, and two night-time sleep opportunities after block of night shifts.

Case study 9
Driver only operations are employed on various services around the country. Given the range of controls available to a driver working alone, without team-mates or back-up, consideration should be given to the type of roster suited to such operations. The early hours of the morning are associated with an increased likelihood of fatigue, which may be exacerbated if the driver is working a 12-hour shift compared to an 8-hour shift (for example). Thus, shorter night shifts may be one control that allow for a longer sleep opportunity and reduce the likelihood of fatigue during the early morning hours. A further control in relation to hours may include fewer night shifts in a row. Further, some operators use Automatic Train Protection as a control for driver-only operations, although it is not in place in all settings and does not replace controls such as hours of work. The same issue may exist for other workers working alone and the specific risks and available controls must be considered.

Case Study 10
A rail operator rosters train crew into resting accommodation on "forward and return" shifts on a regular 24/7 basis, providing an 8-hour break at the resting accommodation. However, agreement with the crews has resulted in a policy that requires a 10-hour break when crews arrive at the accommodation between 0600-1800. This takes account of the circadian influence on sleep during the daytime hours. Furthermore, two of these "forward and return" shifts are often rostered together, with 12 hours off between them. In such cases, a minimum break of 48 hours is provided after the second shift to promote recovery.

There may be circumstances where the risk of ceasing work is greater than continuing such that work right up to the organisational limits is necessary, though only in emergency and with a risk assessment (see 6.1 Exceedances). In all cases, emergencies or otherwise, work cannot occur if the risks are not managed.

Case Study 11
A cyclone is approaching the coast and has taken a sudden and unexpected turn towards the site. If equipment and buildings are not secured, they pose a significant risk to the safety of the nearby town. All hands are required on deck to complete the precautionary tie-down procedures – it will take 90 minutes if all available hands can assist, including those who have been at work for an extended period. Workers are paired up and communication is maintained with all personnel by an incident management team.

Biomathematical models can support a process of schedule management to maximize sleep opportunity. Models can also be used in the hazard identification process to help estimate the level of fatigue associated with a roster and guide decisions around fatigue risk management. Models are not designed to determine safe or unsafe levels of fatigue in individuals but may be used to compare estimated fatigue between different rostering scenarios. They should not be

used as the sole form of fatigue hazard identification because they do not consider all factors that cause fatigue.

Modeling fatigue-related risk
Biomathematical models should be viewed as schedule management tools, not individual worker management tools. When used in conjunction with hours of work guidelines, and a risk management process, biomathematical modeling tools represent a useful tool in the fatigue risk management arsenal – they should not be used in isolation.

Shift swapping should be allowed to cater for individual differences in shift preference provided risk is managed. (See Case Study 3)

Predictability in roster schedules allows individuals to plan sleep and recovery time and provides for regular sleep times.

Short notice scheduling reduces the opportunity to plan ahead in regards to sleep.

Case Study 12
Fatigue risk management programs should include the provision for fatigue reporting by individuals. One operator implementing such a scheme under the heading of "Are U OK?" obtained useful information about particular work situations that gave rise to elevated levels of fatigue, tiring sections of the work roster and problems with noisy resting accommodation. These reports resulted in changes to rosters and the motel providing accommodation.

The operator also introduced a training program for line managers and direct supervisors who are required to assess and action the reports. The training highlighted the recognition of objective signs and symptoms of fatigue and the fact that individual subjective assessments were more accurate in assessing fatigue (tiredness/sleepiness) than impairment (which tends to be underestimated particularly at higher levels of fatigue). In all cases appropriate action must be taken relative to the assessed risk. All such instances are to be documented with repeated episodes followed up by investigation of the work task, schedules and the individual's circumstance.

Overtime should be managed.

Increased journey time to and from work is a factor of modern urban living, and by worker choice it may also occur in rural workplaces. The point here is that it increases wake time associated with the work shift and hence the likelihood of fatigue. Recognition of the risk associate with long commutes by both individual workers and their organisations is important, but management of the risk is best left to the individual and their immediate supervisor. The supervisor will need to be provided with the necessary authority and tools to assist the commuting arrangement in the case of overtime and exceedances.

Forward rotation of blocks of shifts aligns more closely with the body's natural rhythm (i.e. morning shifts then afternoon shifts then night shifts).

Rail transport operators should manage the acclimatisation of workers returning from a period of leave (e.g. A rail transport operator has a policy of not scheduling a worker for night shifts or early morning shifts after coming back from annual or extended sick leave).

5.3 Analysis of fatigue risk

Risk analysis involves considering the consequences of the causes (or sources) of risk, and the likelihood that those consequences will occur. Consequences for an organisation may include injury or harm to any person's health (workers or public), damage to company equipment or services and the environment, damage to reputation, anything that impacts the organisation's objectives. An understanding of what can go wrong if workers are fatigued is the first step in analysis of fatigue related risk. This involves understanding the errors and violations that may occur in relation to particular tasks, and the risks that arise if those errors and violations occur (eg the consequences of a worker falling asleep while driving a vehicle may be serious injury whereas the same worker in a bus has no consequences).

The analysis of fatigue-related risk will be specific to each operational area. If there are significantly different operating conditions, tasks or work patterns within different divisions of the organisation, it may be necessary to assess the risks separately for each division. Operators can build on existing risk assessments where there are comparable elements (see Case Studies 13-15).

Case Study 13

Analysis of the fatigue-related risk associated with on-call arrangements would involve considering the possible consequences of impairment and likelihood that consequences occur (is impairment likely to result in a negative outcome). For example, a signal fitter, having worked a normal day shift, is on-call during the night hours.

Potential Consequences arising from fatigue – error in diagnosis of issue resulting in wrong side failure (reverse signal indications), get hit by train, slip/trips/falls, vehicle accident to or from site.

Likelihood – timing of call, sleep obtained prior to call out, length of call out if it extends the wake period, previous work history (was sleep disturbed previous night), environment (hot, cold), high/low workload, type of tasks (engaging, interactive) and work situation (working alone, worksite protection).

As an example, consider that this fitter was called at 0200 to drive to a relatively remote location at least two hours away. He had work until 1800 the previous day. Assuming there was no alternative but to complete the work immediately, the following controls would need to be considered and discussed with the fitter:

- Self-assessment – are you ok to do this job?
- Options for alternative means of traveling to the job
- An embargo on any further work by this individual for at least 12 hours after completing this job
- Possibility of resting (motel) near the location after finishing the job.
- Train controller to apply blocking facilities to signals that protect the entry of trains into the affected section

Also consider if control measures need to be in place for the next day (e.g. is it appropriate for the person to return to a normal shift the next day and if so what other control measures are likely to be needed and verification of work done by

Case Study 14

A rail wagon maintenance workshop is required to introduce a nightshift in order to deal with a backlog of work. The staff employed has not worked nights before. The workgroup broke down the work into tasks according to criteria based on consequences of errors or short cuts. A risk assessment determines that the potential for fatigue related errors arising from a lack of sleep by employees could have major consequences in terms of injuries and safety problems with the wagons. A range of controls are discussed with the workers concerned and the following arrangements are agreed:

- All staff (including line managers and supervisors) is to be given training in fatigue management and alertness strategies.
- The rosters will use forward rotation with at least two nights off both before and after the night shift week.
- Where possible, the more safety critical tasks were avoided during peak fatigue periods.
- Maximum of five consecutive 8 hour night shifts.
- Work tasks will rotate between individuals and teams with self managed rest breaks rather than rostered times.
- More active supervision to include more communication and active assessment of individuals (e.g Are U OK?) and double checks.

Case Study 15

A major track upgrading has resulted in speed restrictions over several kilometers of the interstate main line. The depot manager is aware that fatigued drivers are more likely to have extreme speed violations under conditions of speed restriction. He is also aware that this route contains considerable curves and gradients that increase the risk of derailment. Trains are being delayed and train crew hours and shifts are being extended to a point where these exceedances require a risk assessment. It determines that the risk of fatigue related incidents has increased to a point where additional controls are required to deal with these circumstances. It was then agreed to:

- Reroster the shifts to shorten them and provide relief crews where practicable.
- Where not practicable – reduce/modify start times and lengths of shifts preceding or following the extended shifts.
- Commuting – Where shifts have been extended by > two hours OR if requested -Company to provide alternate transport home and/or individual to be provided with suitable resting/napping facilities before driving home.
- Individuals to use alertness management strategies as per fatigue management training.
- More active communication by train control (Are U OK?).

Each organisation will have its own context for assessing risks but it is important that fatigue risk factors be assessed using accepted processes (such as provided in ISO 31000 or similar). Analysis can be quantitative, semi-quantitative, qualitative, or a combination and should always include stakeholder consultation to ensure it is comprehensive, appropriate and all risks and hazards are assessed.

5.4 Make decisions about controls and implement

The process of making decisions about controlling or treating the risk requires an understanding of all the risks, all the potential controls, who is involved and how controls would be implemented. Risks can be ranked to allow prioritisation of risk treatments. Risks need to be evaluated against criteria to ensure residual risks are reduced so far as is reasonably practicable. Any ranking process must consider the confidence the group has in the assumptions, conditions and treatments. This confidence may be impacted by current debates amongst experts (industry or academic).

The sub-clauses in Regulation 29 are listed in Figure 4, grouped under key headings. The categorisation assists with understanding in which area of the operation each of the factors is relevant. Some of the sub-clauses fit into more than one category. Figure 4 also provides some examples of controls under each of the categories (illustrative only) and Table 3 contains a range of controls currently used in the rail industry. The list is not comprehensive and organisations should think outside the box in relation to the design of controls and treatments for fatigue-related risk. An often-untapped source of information about local controls lies with the experts who are doing the work every day – the operators at the coalface. Informal and formal practices are employed every day to keep people safe and productive in organizations that use extended hours of operation and require shift work arrangements to maintain their business.

The context of the work must be viewed holistically when analyzing fatigue risk. Unintended consequences can arise as a result of implementing controls without viewing the whole system in which the work is occurring. Refer Case Study 13.

Case Study 16
A train is delayed at around 0300 due to a signal fault, the two driver crew have been on duty for 10.5 hours and are about an hour away from their home depot. Mindful of the 12-hour shift limit set by the Enterprise Agreement, a supervisor suggests calling out relief crew. One of the drivers to be called was not rostered to work at this time and is likely to be asleep. The relief crew will have to drive themselves to the delayed train and the crew being relieved will have to drive the vehicle back to the depot during the early morning hours.

In this scenario the relief actions have the potential to increase the risk of a fatigue related accident while driving the vehicle. A number of decisions and subsequent actions should be considered when assessing the risk of this circumstance. Experience with signal faults would suggest a maximum delay of around two to three hours, as there are safeworking procedures that can have traffic moving even with a total signal failure. However, these degraded safe working conditions in themselves increase risk of errors and increase the need for the operator to be alert.

One of the first steps in assessing the risk is to talk to the crew on the train about their ability to continue working, given that they have an opportunity to rest or nap. The relief crew will take an hour to reach the train and the train crew an hour to drive back to the home depot. By remaining on the train the crew may only work an extra hour compared to the relief scenario.

A holistic view of the risk of the whole operation, including discussions with the crew, determines that, the crew will remain on duty, be reminded of their responsibilities regarding self-assessing fatigue and not to work if they feel safety might be compromised. It is also decided to arrange to meet the train as it gets nearer to the home depot with rostered spare crew signing on at 0500 travelling out (and the crew returning) by taxi.

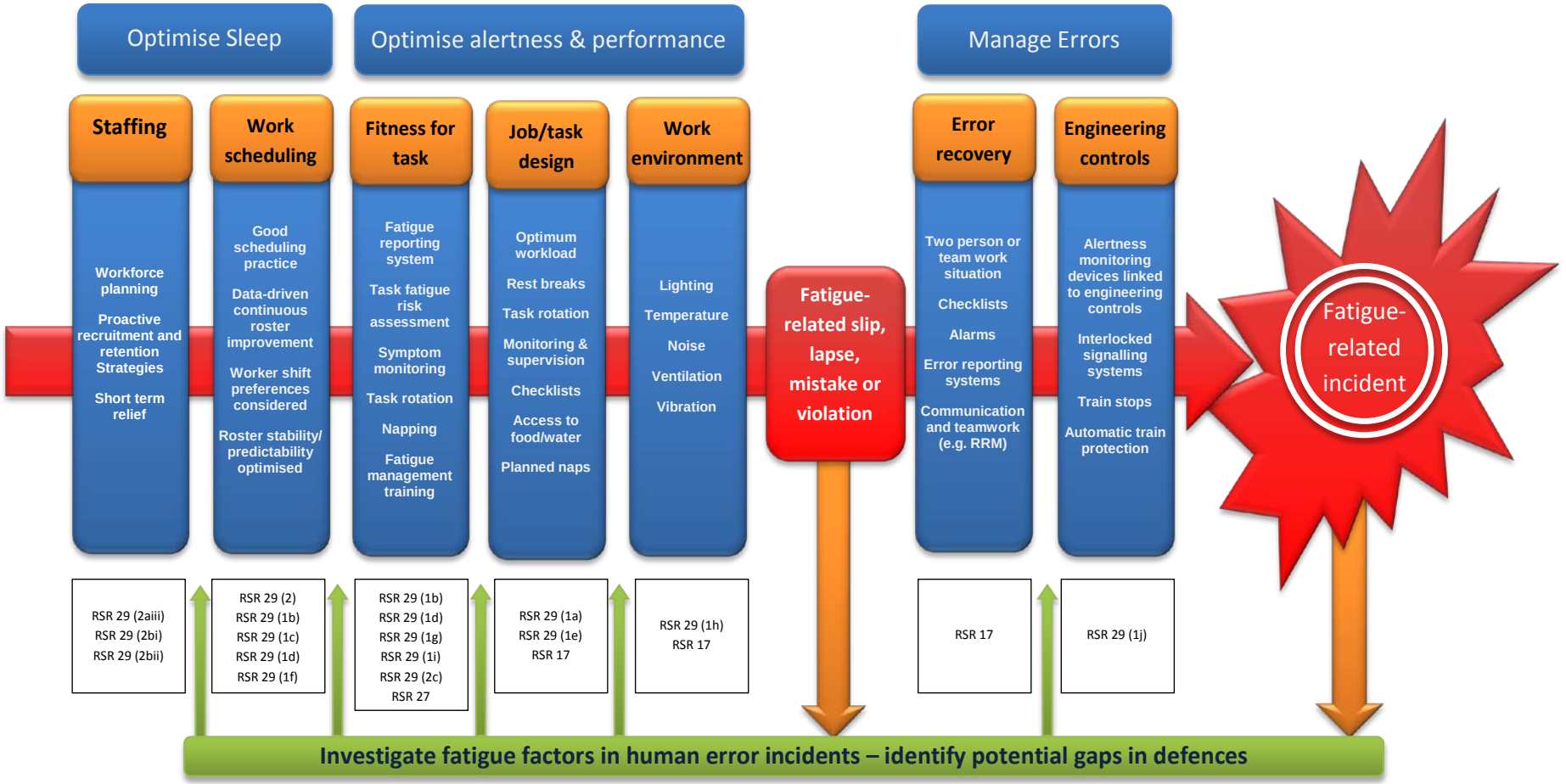
Based on the range of options identified and the decisions made about which controls should be implemented to manage the risks, organisations should document the risk treatment plans and processes and implement in conjunction with stakeholders. Plans should include controls, actions, accountabilities, resources required, performance measures and review processes. All reasonably practicable controls must be implemented.

Regulation 29 from the Rail Safety National Law outlines a series of factors that organisations should take account of in their fatigue management process. Table 2 provides some detail around specific considerations in relation to each sub-clause, which can be used to understand the hazard and to identify potential controls.

Table 2 - Issues that organisations need to think about in relation to the factors listed in Regulation 29

Clause 29(1)	Considerations
(a) - scheduling of work and non-work periods, including time-on-task and rest opportunities in shifts and the total period of time in which work is being carried out.	- time on task effects, length of wake, opportunity for sleep between shifts, breaks within shifts, circadian effects on sleep and waking function
(b) – call-in, on-call and lift-up and lay-back arrangements and extended hours of work, including overtime.	- time on task, length of wake, disruptions to sleep, difficulty planning/preparing for work (sleep), circadian effects on sleep and waking function
(c) – the impact of work scheduling and relief practices generally on social and psychological factors that may impact on performance and safety, including the effect of scheduling practices, schedule predictability and irregularity and control over work hours on sleep loss, performance and safety.	- opportunity for sleep and for planning sleep, viewing rosters as more than just about fatigue management, work hours and work/rest arrangements (FIFO camps, depot or crew cab rest) impact significantly on non-work life (domestic, family, social, leisure), work-life balance equation and psychosocial well-being.
(d) – physiological factors arising out of work practices affecting rail safety workers, such as the effect on worker alertness and recovery of the time when work is undertaken, the length and frequency of breaks, commuting time, circadian effects, extended wakefulness, chronic sleep loss effects and sleep inertia.	- circadian effects on alertness and performance, importance of breaks within shifts, commuting time reducing opportunity for sleep, timing of commute (e.g. after a night shift), cumulative effect of reduced sleep over a series of shifts, performance impairment immediately upon waking.
(e) the kind of rail safety work being carried out, including – (i) work that requires significant physical exertion or high cognitive task demand; and (ii) the degree of monotony or boredom or low cognitive tasks demand of the work.	- high workload may exacerbate fatigue, low workload may make people more susceptible to effects of fatigue
(f) – the variations in shifts and rest periods that may be required by different rail safety work requirements, including different routes, crew-call practices and predictability of working hours.	- difficulty planning/preparing for work (sleep), consistent timing of sleep periods (day to day)
(g) – the suitability of rest environments, including barracks, rest house and relay vans provided for rail safety workers but the operator.	- sleep affected by heat, light and noise
(h) – the physical environment in which rail safety work is to be carried out, including climactic conditions, noise, vibration and fumes.	- shift length, added stressors, impact on performance and alertness
(i) – fatigue risks arising from any one-off or occasional circumstance in which rail safety work may be required to be carried out, including in emergencies or under degraded or abnormal conditions, subject to the working hours being dependent on the rail safety workers' indication of their fitness to continue.	- self-assessment of performance when fatigued, use of objective measures of risk, application of appropriate controls, impaired performance.
(j) – relevant developments in research related to fatigue and any technology that may be applied to manage work-related fatigue.	- keeping up to date, distributing information to appropriate personnel in organisation, inclusion in training programs, critically reviewing technologies and tools.

Regulation 29 – clause (2) pertains to the requirement to maintain documented procedures to manage fatigue-related risk associated with scheduling practices that provide for safe hours of work, monitoring hours of work, as well as education and training. Figure 4 below, and Appendix A provide some further information about work hours and fatigue-related risk.



Based on Reason, J 1997, Managing the risks of organizational accidents, Ashgate, Aldershot

Figure 4 – The schematic provides some examples of controls that could be implemented as part of a fatigue risk management program within the Safety Management System. Controls are aimed at optimising sleep opportunity, optimizing alertness and performance and managing errors. Sub-clauses of Reg 29 (and other relevant regulations) are categorised under key themes (see Table 2 for more detail). In addition to providing avenues for reducing the likelihood of elevated fatigue, the controls also provide opportunity to investigate incidents and identify gaps in the defences (see Appendix C). Figure provided by ITSR adapted from Reason (1997); Moore-Ede et al (2009); Dawson and McCulloch (2003).

Table 3 - controls used by industry as part of fatigue risk management categorized according to Organisational/Scheduling controls, Team-based controls, Individual controls and Engineering controls. Appendix C contains further detail about some of the tools currently used or being discussed in the rail industry – this includes information about the benefits and important considerations for their use.			
Organisational/Scheduling	Team	Individual	Engineering – rolling stock/infrastructure
- Adequate resourcing to meet scheduling requirements - Work scheduling practices that provide for safe hours of work (See Figure 2) - Hours of work specified by enterprise agreements and awards - Roster relief to manage excess shift lengths - Self managed rest breaks - KPIs related to FRMP monitored and actioned when appropriate according to responsibility - Organisation has and promotes *just culture* policy to support self-reporting of fatigue - Regular reporting and analysis of data related to fatigue related incidents - Alternate transport home provided where required - Provision of suitable resting/napping facilities - Training for Rail Safety Workers and rostering personnel - Medical Fitness standard - Employee assistance program - Accommodation standards for work-related rest facilities - Transport to/from worksite (camps/residential) - Health and well-being program	- Roster relief to manage excess shift length - Increased supervision/ contact via radio or phone - Employ double checking systems (e.g. cross calling commands) - Task rotation (where practicable) - Napping as per policy - Reassign to lower risk job - Allow sleep to be obtained before commencing shift - Self managed rest breaks - Peer reporting to supervisor if others are exhibiting signs - Supervisor to assess risk of continuing duty (using individual sleep report, symptom checklist, employee-rated fatigue level see checklist) - Options for removal from duty and provided with transport to home - No handover to a person perceived to be fatigued - Increased supervision for employees identified “at risk” - Include fatigue in pre-start briefings or toolbox meetings - Rail resource management (RRM)	• Napping as per policy. • Increased supervision/ contact via radio or phone where possible • Alertness management strategies (caffeine, interaction, exercise etc) • Reassign to lower risk job. • Sleep before commencing shift. • Self-managed rest breaks. • Self-assessment (prior sleep/wake, exhibiting signs, symptom checklist) - Asking if OK. • Peer reporting to supervisor if others are exhibiting signs. • Not to handover work to a person perceived to be fatigued.	• Automatic Train Protection Systems • Interlocked signals and signal overlaps • Vigilance controls • Design of alarms and visual cues such as colour coding • Track side signage • Derailers • Data loggers assisting incident investigation • Ergonomic design of working environments

Case Study 15

A team signs on for a shift starting at 2230 and will book off at 1030 the following day. Team members chat amongst themselves about how much sleep they got during the day and how they are feeling. Decisions are made about who takes the lead for the start of the shift and how they will manage the night’s work.

5.5 Evaluation of the effectiveness of controls

Risks need to be evaluated against criteria and treated to ensure residual risks are managed so far as is reasonably practicable. This involves a process of considering what additional controls are available and justifying adoption, or rejection on the basis of what is reasonably practicable for your organisation.

- The effectiveness of the controls can be measured
- Information is collected to inform continual improvement of the fatigue risk management program
- The findings from investigations of errors, incidents and near misses are fed back into the system
- Changes in any context are detected
- Emerging risks can be identified quickly

The FRMP should be reviewed at least annually, in accordance with legislative obligations, as identified as appropriate in a suitable risk assessment, after any occurrence in which fatigue was a contributing factor, and where controls (or risk treatments) have been implemented. The evaluation process can be undertaken in a range of ways including:

- Inclusion in a Rail Transport Operator's compliance audit plan;
- Reviewing actual hours worked against rostered hours, and the Rail Transport Operator's policy in this respect;
- Involving Safety Representatives in periodic inspections;
- Management conduct safety tours or inspections;
- Direct feedback from Rail Safety Workers and other relevant stakeholders; and
- Review occurrence data.

Reviews should also be undertaken to ensure the currency of the System.

Where the evaluation process identifies a requirement for further assessment or re-assessment then the cycle should be completed again.

Appendix C outlines a range of tools that may assist in the assessment of fatigue-related risk through the identification of increased fatigue likelihood and the evaluation of current controls.

Fatigue Risk Management Program Checklist:

1. Has the organisation identified all relevant legislation and regulations?
2. Does the organisation have a fatigue management policy?
3. Does the organisation have a documented process for managing fatigue-related risk that ensures relevant risk management processes are applied
4. Has the organisation given consideration to the work hours in relation to limits to total hours or number of shifts in a week, fortnight, month; maximum consecutive shifts; minimum length of time between shifts; length of day and night shifts?
5. How are actual and planned hours of work monitored and reviewed?
6. Are there strategies in place to maintain alertness/detect impairment?
7. Are there processes for ensuring personnel are fit for duty?
8. Does the organisation have a process for educating and training personnel?
9. Is the FRMP audited and reviewed?

6 Reviewing Performance

Fatigue Risk Management Programs should be designed in such a way that mechanisms are in place to evaluate the program to determine strategies that are working well and to identify any areas for improvement. There is a range of options available for evaluating the success of a fatigue risk management program. Based on the risk assessment these may include:

- Measuring deviations of actual hours worked from planned hours of work and reviewing these against the Rail transport Operator's benchmark levels.
- Sample Key performance indicators that can help review performance include:
    - number of consecutive duties (night, early morning, day) in a period
    - percentage of duties starting earlier than previous (e.g. backward rotation)
    - percentage of free evenings/weekends
    - average break following night work
    - use of biomathematical models to assess sleep opportunity in schedules
    - time above organisational tolerance levels (individuals and business units)
    - absenteeism
- Reviewing Incident and/or Occurrence data - fatigue should be investigated as a potential causal factor in occurrences (unscheduled events/incidents/accidents);
- Ensuring that staff who monitor, develop and implement rosters are trained and aware of the impacts of how work hours can impact fatigue risks;
- Reviewing the procedures for workers who present as not fit for duty - ensure that they are being implemented using just culture practices and robust non-punitive human resources procedures;
- Identifying the frequency of rail safety workers presenting as not fit for duty because of fatigue related issues;
- Analyse data from the Just Culture fatigue reporting system;
- Using external or internal consultants for expert technical advice;
- Collecting feedback from rail safety workers including Work Health and Safety Representatives (e.g. using a survey such as the Standard Shiftwork Survey http://www.workingtime.org/technical);
- Including fatigue as a standard agenda item for discussion at management safety meetings, Work Health and Safety Committee meetings or other forums – gather information about how fatigue-related risk being managed in all areas; and
- Reviewing records of staff that have completed designated training.

Relevant fatigue management information should be made available to rail safety workers and their representatives to assist the evaluation process.

6.1 Exceedances

It is important to ensure that standards and limits that have been identified and set in the risk management process are only exceeded with prior approval and infrequently in exceptional circumstances. This is to avoid employees working excessive hours (e.g. overtime, on call duties). Safety briefings, planned or delayed training, long-standing job vacancies, a block of maintenance work extending over a few days and organisational changes are not reasons for exceeding set limits. They are all foreseeable circumstances that should be taken into consideration when planning or altering rosters.

Once company standards and working limits have been set it is good practice to provide clear criteria for those infrequent and exceptional circumstances where limits can be exceeded. The controls required to ensure all risks are mitigated should also be defined. Factors for consideration, depending on the risk environment are:

- The outer limits which workers should not exceed (i.e. what is an acceptable level of overtime, number of call-outs, number of times an additional shift may be permitted in a roster period?).
- Clear criteria for when limits may be exceeded on an infrequent one-off basis (i.e. failed trains, extreme weather) and the controls in place.
- A documented process for whom has responsibility for authorising exceedances, and under what circumstances.
- Capacity of rail safety worker to continue working safely.
- Circumstances when safety critical workers can decline to continue working beyond agreed limits.
- Clear means of reporting exceedances, summarising the risks considered and corresponding fatigue controls and mitigation measures put in place.
- Limiting the availability of worker following additional hours of work.
- Actively monitor the risks and review the outcomes
- How the company will examine the differences between master and actual rosters to allow for continual refinement of the master roster
- Utilizing a fatigue risk modeling tool
- Consultation – employee buy-in; how have employers consulted with their employees?

Those with responsibility for overseeing the FRMP should be notified of exceedances for as part of the continuous review process.

Case Study 17

A five-day line closure is planned due to Track relaying and signaling upgrade requirements. All staff involved will be working 12-hour shifts with 15 minute handovers at the start and finish, with no off duty days. Some of the engineering supervisory staff involved do not regularly work at nights. The project planners conduct a risk assessment into these working arrangements and determine that fatigue related errors due to a lack of sleep could have very serious consequences and the risk tolerability framework determines the risk to be extreme. A forum of stakeholders, with representatives from all the work groups involved come up with the following suggested range of controls for this risk.

- A maximum of three consecutive night shifts to be worked, with at least two nights off between night shifts.
- Work schedule to be assessed using a biomathematical model as one tool to ensure maximum sleep opportunity is provided.
- All staff (including line managers and supervisors) are to be given training in fatigue management and alertness strategies.
- Fatigue to be discussed at prestart “tool box” safety sessions
- Measures will be introduced to enable fatigue to be assessed at an individual level, including self-assessment in regard to their ability to continue to work safely.
- More active supervision to include more communication (are you OK?) and double checks.
- Work tasks will rotate between individuals and teams with self managed rest breaks rather than rostered times.
- Facilities to be provided for napping during breaks and before self-driving (at end of shift).
- All staff involved rostered off for minimum 36 hours before returning to normal roster

These measures will reduce the risk from extreme to a moderate level.

A Causes and Consequences of Fatigue – Supporting Literature

A.1 Fatigue and the Rail Industry

Rail operations in Australia provide services around the clock and around the country. Night work, morning and evening peak hours, long-haul routes, maintenance schedules, emergency repair work and infrastructure development mean extended or irregular hours and shiftwork for many rail workers. Some shiftwork patterns, or extended/irregular hours increase the likelihood of fatigue and impaired performance, change the error profile and in some cases, increase the frequency of incidents and accidents. Managing fatigue-related **risk** requires an understanding of the sources of fatigue (i.e. the factors that increase the likelihood that a worker is fatigued and therefore impaired), as well as an understanding of the potential consequences of impairment in a given work setting.

While consequences are determined largely by the context in which the work happens and the tasks the worker is completing, likelihood is determined by factors influencing sleep, wake and circadian disruption. The focus of this literature review is factors that increase the likelihood that an individual will be fatigued and therefore impaired. The review draws on laboratory and field-based research from around the world and also details studies specifically focused on rail operations. The review concludes with a brief discussion of the current approach to managing fatigue-related risk that goes beyond a single focus on work hours.

A.2 What is Fatigue (section 2.1)

Fatigue involves a decreased capacity to perform mental and/or physical tasks and feelings of tiredness, but may also be associated with a desire to rest, and unpleasant psychological/ physiological sensations. This type of fatigue arises from inadequate sleep (either through reduced sleep duration or poor sleep quality), extended wakefulness, and time of day (circadian factors). Causes can be work-related (e.g. long hours or night work), or nonwork-related (e.g. family commitments, illness). Fatigue manifests in a wide range of consequences that include mental and physical performance impairments.

A.3 Causes of Fatigue (section 2.2)

The factors that cause fatigue are inadequate sleep, extended periods of wake and time of day.

A.3.1 Time of Day

Humans are biologically programmed to be active during the day and rest at night and a circadian clock in the brain drives that rhythm. The clock also responds to light information from the environment such that under normal circumstances we remain synchronised to the day/night cycle (Aschoff 1965; Wetterberg 1994). Workers on shiftwork rosters or irregular or extended hours need to sleep when their biological systems are driving them to be awake, and work when they are driven to sleep. When sleep occurs out of sync with the biological clock and the day/night rhythm, it is often shorter and more disturbed (Tepas and Carvalhais 1990; Siebenaler and McGovern 1991; Akerstedt 1998b). For example, average sleep duration of 253 locomotive engineers was up to 2 hours longer when they slept at night compared to when the sleep was during the day (Roach et al. 2003). Similar findings were reported in other studies examining the impact of timing on sleep length (Akerstedt et al. 1991; Akerstedt 1998b; Ingre et al. 2008), demonstrating that the timing of work hours, and therefore the timing of sleep opportunities or breaks impact both the quality and quantity of sleep.

The circadian rhythms of alertness and performance mirror the circadian cycle of core body temperature. This means that performance peaks in the early hours of the evening when temperature is high, and is lowest in the early hours of the morning during the trough in the rhythm of body temperature. This trough in alertness and performance is sometimes called the window of circadian low (WOCL). There is also a secondary dip in alertness and performance in the early hours of the afternoon (Krauchi and Wirz-Justice 1994; Lack and Lushington 1996). It is for this reason that working during the night hours increases the likelihood of fatigue. This increase in fatigue is reflected in accident statistics from road crashes and other transport sectors, with black spots in the early hours of the morning and the after-lunch period (Smith et al. 1994; Akerstedt 1995; Folkard 1997; Hanecke et al. 1998; Folkard and Akerstedt 2004; Williamson and Friswell 2011). It is also clear from the research that early hours of the morning carry a higher likelihood of fatigue and impairment compared to the early evening hours, even if one has slept a reasonable amount in the previous 24-hour period. However, if sleep has also been reduced, or wake is extended, the impairment is likely to be significantly higher (Zhou et al. 2010; Dijk et al. 1992). The interaction of work timing and sleep timing can result in a very high likelihood of fatigue and impairment; for example, in situations where work occurs at 0300 and prior sleep has been poor quality or short. It is intuitive then that night work is associated with higher likelihood of fatigue and impairment due to the impact on sleep and waking function.

The signal from the biological clock that drives us to sleep at night and be awake during the day is also the reason that early starts are associated with increased likelihood of fatigue. Early starts require early wake times and in situations where the commute is long, wake time may be up to two hours prior to shift start (Tucker et al. 1998). However, due to the biological rhythm alertness, it is difficult to get to sleep in the early evening hours to compensate for the early rise. In summary then, time of day factors are critical for sleep quality and quantity, and for alertness and performance.

A.3.2 Sleep Quality and Quantity

It is generally accepted that people require, on average, 7-8 hours of sleep per night for the body and mind to function at peak (Ferrara and De Gennaro 2001). While six hours of sleep may be associated with minor impairments in the short-term, successive short sleeps (less than 8 hours) do result in impairments. Further, the long-term effects of short sleep are not well understood (Ferrara and De Gennaro 2001; Belenky et al. 2003). A key point is that the amount of sleep one needs depends upon what one is doing. Safety critical work requiring vigilance, alertness, attention, decision-making etc may be compromised by a lack of adequate sleep due to inadequate time between shifts.

Cumulative sleep loss occurs when an individual gets insufficient sleep over consecutive days. This type of sleep loss is common due to irregular schedules, extended shifts, consecutive shifts and/or night shift. For example, research involving locomotive engineers showed that a backwards rotating shift schedule – where shifts start earlier each day or over a few days across the roster period – resulted in a cumulative sleep debt of 2 to 4 hours per night (depending on the rotation schedule) (Thomas and Raslear 1997) due to the period of time available for sleep between shifts. Further, in drivers and controllers working irregular schedules, the specific pattern of shifts impacted the amount of sleep obtained (Sallinen et al. 2003). Sleeps between night shifts were the shortest and morning shifts preceding night shifts also resulted in curtailed sleep. A study of 269 locomotive engineers and 35 terminal operators from 16 Australian rail depots, who also worked irregular schedules reported sleep duration prior to a night shift was significantly less than prior to a morning or afternoon shift (Kandelaars et al. 2005). Regular shifts of 12 hours in length are associated with approximately six hours of sleep, whether in a camp or at home, in mining or manufacturing (Ferguson et al, 2010; Tucker et al, 1998). Sleep

loss accumulates over a number of consecutive shifts if workers get less sleep than they need each day.

Organisations involved in rail operations in Australia use a variety of rosters. Most involve one shift per 24-hour period but relay operations divide the work between two crews who alternate every 8 hours between work and rest in the crew van. The model is not unlike watch-keeping schedules used in maritime settings. A series of studies were conducted with relay drivers in Australia to determine how the pattern of work impacted drivers' sleep. One study investigated the sleep of drivers on a ~90 hour trip and found that even when the 8-hour break time coincided with the optimal time for sleep – started between 2200-0000 – the average amount of sleep obtained was less than 5 hours. This is not surprising given the fact that drivers do other things in their breaks besides sleep. Further, breaks occurring during the daytime were associated with short sleeps of just over 2h when breaks started between 1000-1200 (Jay et al. 2006). Importantly however, the relay pattern provides for sleep more frequently than non-relay shifts. Average sleep per 24 hours across the trip, including pre- and post-trip sleeps at home was 6.3 hours. A longer trip encompassing approximately 110 hours also resulted in an average of approximately 5 hours of sleep per 24-hour period (Darwent et al. 2008) and a shorter trip of approximately 40 hours resulted in between 5 and 6.6 hours of sleep per 24 hours depending on the roster worked (Lamond et al. 2005). Together these studies indicate that a number of factors are important for sleep – the length of the trip, the roster (whether a crew starts the trip working or resting), the crew van facilities and the recovery opportunities between trips.

A.3.2.1 Sleep location

Environmental factors such as movement, noise, temperature and vibrations can impact on sleep (Knauth and Rutenfranz 1975; Arnberg et al. 1990). Using indices of sleep quality derived from actigraphic records of sleep/wake, researchers demonstrated that train drivers' sleep quality was higher at home than in sleeper berths in trucks, at depots or at home (Baulk and Fletcher 2012; Darwent et al. 2012b). Interestingly, both studies reported lower subjective quality of sleep away from home. While time of day factors may well have contributed to poorer sleep quality in these circumstances (as sleep at work was not always obtained during the optimal night-time hours) similar findings have been reported in studies where 'work' and 'home' sleeps of similar timing have been compared (Parkes 1994; Ferguson et al. 2008; Ferguson et al. 2010). Home sleep in many situations is longer due to longer opportunities.

A.3.2.2 Recovery opportunities

Recovery opportunities within and between shifts are critical for managing fatigue. Laboratory studies have demonstrated that following a period of cumulative sleep loss, performance may not recover to baseline levels for a number of days, even after sleep is once again extended. In a laboratory study, three 8-hour sleep opportunities were not sufficient for complete recovery following a week of restricted sleep (Belenky et al. 2003). This has implications for roster and break time scheduling within the rail industry. Recovery opportunities within shifts are also important as rest breaks have been shown to be effective at reducing the level of fatigue and accident risk (Tucker et al. 2003). If the rest break includes a nap then alertness and performance also benefit (Sallinen et al. 1998; Macchi et al. 2002; Lovato et al. 2009).

A.3.3 Hours of Wake

In general, the longer an individual remains awake, the stronger the drive for sleep, and the higher the fatigue level. Research has shown that long shifts (12 hours) are associated with higher levels of fatigue than shorter shifts (8 hours) due to extended wakefulness and attention demands (for review see Rosa 1995; Smith et al. 1998). Further, night shift is associated with higher likelihood of fatigue as workers may be awake for several hours prior to a night shift (Knauth et al. 1980). While the amount of wakefulness prior to a dayshift is typically 1-2 hours, a night shift worker may be awake for 10-16 hours before beginning their shift. By the end of the shift, they may have been awake for as much as 22 hours (Akerstedt 1998a). Throughout this time, the pressure to sleep increases (Folkard et al. 1999; Belenky et al. 2003) and the increased risk of an incident with longer shifts may in part be due to extended wake (Tucker et al. 2003). A large study examining the duty rosters of almost 300 rail employees demonstrated longer wake times at the end of both afternoon and night shifts than at the end of day shifts (Kandelaars et al. 2005). Another factor known to impact the amount of sleep workers get is travel time: the longer the commute to work, the shorter sleep people got (Basner et al. 2008). The drive for sleep increases with each hour of wakefulness and the consequences for performance are significant (see Fatigue and Impairment).

In addition to the primary causes of fatigue – inadequate sleep, extended wake and time of day – other factors are known to influence the levels of fatigue including workload, individual factors including health, domestic and social situation, and work and non-work stresses.

A.3.4 Workload

Workload refers to the type and intensity of tasks, performed in the workplace. Mental and physical fatigue can occur when the workload is either very high or very low. Specifically, tasks that have a very low cognitive load can result in loss of interest and boredom, increasing the effects of fatigue (Richter et al. 2005). Train drivers can experience long periods of monotony with unchanging landscape and speed and few or no train crosses (Jay et al. 2008). In other settings, workload can be extremely high with multiple stations, signals, crossings and passengers (Thompson, Rainbird et al. 2010).

Those tasks with a very high cognitive or physical load result in fatigue due to excessive demands on attention and/or body (Baulk et al. 2009). Although a small study, research examining the relationship between workload and fatigue in a sample of metallurgic smelter employees reported higher levels of fatigue during high workload shifts, particularly during night shifts (Baulk et al. 2007). Fatigue resulting from workload becomes an increasing concern when combined with extended shifts with research reporting that the relative risk of an incident after 12 hours of work is twice that after 8 hours of work (Folkard and Tucker 2003). Thus, although many positions within rail operations may not demand a high physical load, situations of high cognitive load are common.

A.3.5 Individual factors

Individuals sleep differently, have different sleep needs and respond to sleep restriction differently. In the same way, there is a lot of individual variation in domestic, social and health status and demographics and social factors have been linked to differences in fatigue levels (Di Milia et al. 2011). For example, research has shown that sleep quality and quantity naturally reduces with age (Akerstedt and Gillberg 1981) and older shift workers are particularly susceptible to fatigue as they report shorter and more disturbed sleep than younger shift workers (for review see (Folkard 2008). Social circumstances or pressures, such as marital status, number of children and leisure interests, will influence levels of fatigue by impacting on

the extent to which an individual is able to acquire sufficient sleep. Family responsibilities may lead to short sleep duration and extended wakefulness, especially in shift workers. Health status, including lifestyle choices can also negatively impact on sleep and therefore contribute to worker fatigue.

Smokers are reported to have more disturbed sleep, typically taking longer to fall asleep and experiencing more wake time during a sleep period (for a review see (Jaehne et al. 2009). Conversely, healthy lifestyle choices such as good physical fitness and a healthy diet have been reported to reduce fatigue and improve alertness and performance in shift workers (Harma et al. 1998). Shiftwork sleep disorder is a recently classified circadian rhythm sleep disorder characterized by excessive sleepiness but also is associated with trouble sleeping, reduced performance, depressed mood (ICSD) and prevalence estimates are as high as 30% for night workers (Drake et al, 2004).

In addition to the biological drive, and the influence of work hours, sleep/wake patterns are also subject to social influences. That is, family or social responsibilities are prioritised above sleep, especially for shift workers whose work/rest cycle is out of sync with the patterns of family and friends. Understanding the social influencers of sleep is important for both employers and employees in relation to fatigue management (Monk and Wagner 1989; Darwent et al. 2012a). It is clear then that both work- and non-work related factors can influence the time available for sleep, the amount of sleep that is actually obtained, the length of wakefulness and the times of day that one works and sleeps.

A.4 Consequences of Fatigue

The consequences of fatigue include:

- decreased alertness,
- slower reaction time,
- poor hand-eye coordination,
- poor communication,
- higher error rates,
- reduced vigilance,
- impaired decision-making,
- microsleeps,
- mood swings,
- impaired short-term memory,
- underestimation of performance,
- impaired judgment,
- lethargy, and
- loss of situational awareness (for reviews see Pilcher and Hufcutt 1996; Harrison and Horne, 2000).

Laboratory-based research demonstrated that reducing sleep by as little as 1-2 hours over a short period of 4-7 days resulted in high levels of fatigue and performance impairment (Belenky et al. 2003; Van Dongen et al. 2003). Indeed, research has suggested that cumulative sleep loss may have a greater impact on alertness and performance than acute sleep loss (Pilcher and Hufcutt 1996). In addition to cumulative sleep loss, extended wake also results in impairments in performance. The degree of performance impairment associated with 18-26 hours of sleep deprivation is similar to that seen at a blood alcohol concentration (BAC) between 0.05% and 0.10% (Dawson and Reid 1997; Lamond and Dawson 1999; Williamson

and Feyer 2000). These laboratory-based findings are supported by statistics from workplaces and from the road suggesting that the risk of incident and accident increases after eight hours at work and rises with each subsequent hour (Hanecke et al, 1998; Dembe et al. 2005; Folkard and Tucker. 2003). Further, information about sleep, work and injuries was collected from more than 74,000 individuals in the USA and showed that both daily sleep and weekly work hours were related to the likelihood of a work-related injury (Lombardi et al. 2010). In addition to such studies, research from the rail industry also reports increased sleepiness and impairments in performance associated with certain characteristics of work hours.

Studies show that train drivers do experience drowsiness and occasional microsleeps whilst driving (Akerstedt and Torsvall 1983; Cabon et al. 1993; Dorrian et al. 2007b). A study by Harma and colleagues used diaries and questionnaires to examine the sleep and sleepiness of train drivers and controllers (Harma et al. 2002). Fifty per cent of drivers and controllers reported severe sleepiness on night shift and the risk of sleepiness increased 15% with each hour on shift. But, the risk of severe sleepiness was reduced 15% for each hour of sleep the workers had prior to their shifts (Harma et al. 2002). Thus the timing of the shift, the length of the shift and their sleep history were all important factors for their sleepiness. The relationship of sleepiness with safety measures is also important.

Forty rail accidents and incidents in Australia were examined and the results showed that the largest human cause was decreased alertness (Baysari et al. 2008). A smaller study examining six rail accidents/incidents in the United States identified 36 possible contributing factors. One fifth of the contributing factors were fatigue related - skill based errors, attentional lapses and memory failures (Reinach and Viale 2006). Rail operations are susceptible to the impairment caused by fatigue due to the types of work tasks undertaken.

High-fidelity rail simulator studies have shown that an increase in fatigue levels in train drivers is associated with reduced alertness, missed alerter signals, failure to sound the horn at grade crossings, increased usage of fuel, increased speed violations and braking errors (Thomas and Raslear 1997; Dorrian et al. 2007a). In addition, simulator studies showed that when drivers move from a state of moderate to extreme fatigue, behaviour shifts from impaired driving performance to a state of cognitive disengagement (Dorrian et al. 2007b). This means that the drivers essentially ‘switch off’ from the driving task. The implications are obvious and are of particular concern for drivers and controllers who are required to stay constantly alert, often in monotonous conditions, to respond to irregularities and ensure crew, passenger and community safety (Edkins and Pollock 1997).

The impact of fatigue can also be estimated in terms of productivity and efficiency. Using information collected by data loggers in 50 locomotives, Dorrian and colleagues investigated the effects of fatigue on key driving performance indicators (Dorrian et al. 2007a). Drivers were categorised into three groups - ‘low’, ‘moderate’ and ‘high’ fatigue - based on biomathematical modelling of their 7-day prior work history. Comparison of the three groups showed that heavy brake violations increased and dynamic brake use and throttle manipulation decreased as the drivers became more fatigued. Fuel usage was also higher in the high fatigue groups. Drivers in the high fatigue group had the greatest fuel consumption and in fact exceeded the maximum target fuel rate for the particular train corridor they were driving. The difference in fuel usage between the low and high fatigue groups was estimated at 9%, equating to a direct operational weekly cost of $3512 per week or $182 655 per year (Dorrian et al, 2007a). The impact of fatigue on productivity and efficiency is rarely examined but an obvious benefit can be achieved with appropriate management.

A.5 Fatigue Countermeasures

While sleep is ultimately the only remedy for fatigue, a number of countermeasures have been examined that provide short-term alleviation of fatigue-related symptoms. The primary countermeasures are caffeine and naps. Caffeine affects alertness levels, sleepiness, sleep propensity and performance on a range of different tasks. In particular, caffeine improves the performance of sleep deprived individuals on reaction time tasks, simulated driving tasks, brain activity and mood measures (see Jay et al. 2006; Reyner and Horne. 2000). The half-life of caffeine is approximately 3-5 hours and given that caffeine can impair one's ability to fall asleep, the timing of ingestion should be strategic. In addition to caffeine, napping is commonly used as a fatigue countermeasure.

Short sleeps in the form of naps have been shown to provide measurable boosts in alertness and performance for a number of hours following the nap (Driskell and Mullen. 2005). Naps as brief as ten minutes have been shown to be effective, providing opportunity for naps to be used in operational settings to manage the risk of fatigue-related errors. In addition to the benefits of short sleeps, alertness and performance may be impaired immediately upon waking – a state called sleep inertia (see Jewett et al. 1999). The likelihood of impairment during this period is increased and research suggests that it can last for up to an hour but is dependent on a number of factors – the degree of prior sleep restriction, sleep stage at waking and time of day. Interestingly, caffeine can reduce the effects of sleep inertia and thus these countermeasures can be used in combination. It is also the case that a prophylactic nap in the afternoon results in improved performance across the night shift (compared to a no-nap condition) (Macchi et al. 2002) and also increases the efficacy of a short nap during the night shift (Lovato et al. 2009).

A.6 Approaches to Fatigue Risk Management

The general principles of safety management systems theory (Reason 1990) applied to fatigue risk management seek to manage fatigue by reducing the likelihood that fatigued individuals are operating in the workplace and to reduce the consequences of any errors they make if they are in the workplace (Dawson and McCulloch 2005). A major issue with relying on prescriptive hours of service rules is the assumption that fatigue-related risk is managed by regulating the amount of time spent at work. An individual could be operating within the Hours of Service rules but still be impaired (Dorrian et al. 2004; Dawson and McCulloch 2005). As fatigue results from a number of different factors, including work and non-work related factors, an individual working at night may be fatigued due to the biological drive for rest (i.e. reduced alertness and performance) or because they didn't sleep during the day due to caring for a sick partner. Where Hours of Service rules operate in isolation and not as one component of a fatigue risk management program, there are no other defences.

A risk- and safety management systems approach to fatigue management is one that develops and implements multiple strategies to manage fatigue-related risk. This approach to fatigue risk management can be represented using a hazard control framework proposed by Reason (1990). In Reason's theoretical model, known as the 'Swiss Cheese Model', a workplace accident or incident is the end point of a sequence of events or an 'error trajectory'. According to Reason, the chain of events preceding a workplace accident or incident passes through a number of 'holes' in the system, represented by weaknesses in safeguards and controls. These 'holes' can be identified as unsafe acts, local workplace factors and organisational factors.

In the specific case of a fatigue-related incident, four levels of the error trajectory have been identified: sleep opportunity, actual sleep obtained, behavioural symptoms, and fatigue-related errors (Dawson and McCulloch 2005). An effective fatigue management program addresses each of the four levels by assessing or identifying the likelihood of fatigue and impairment and

implementing appropriate control mechanisms. A fifth level is added to investigate incidents that occur and ensure effective future risk mitigation strategies. It is important to note that this model does not take account of the context in which the work is happening. Thus, it cannot look at the potential consequences of elevated fatigue or impaired performance; it focuses solely on the likelihood of fatigue.

A recent review article by Gander et al. (2011) identified a number of organisational/industry level factors that play pivotal roles in the efficacy of a fatigue management program. The safety culture is particularly important and in this context assumes that errors and lapses in safety are opportunities to learn. A culture of trust between employees and management is also key given the reliance of fatigue risk management on the reporting not only of errors and incidents but also symptoms of fatigue and instances of inadequate sleep or extended wake. In addition, consideration of operational complexity and fatigue risk, remuneration and disincentives for safe behaviour, the impact of commuting and how the organisation handles employees with sleep disorders are also listed as being important to the efficacy of fatigue management programs (Gander et al. 2011).

A.7 Summary

The sources of fatigue are well understood. When fatigue levels are elevated there is an increased likelihood of impairments to performance and alertness, with potential ramifications for safety and health in the workplace. However, the ramifications or consequences of fatigue in the workplace are dependent on the work context. Thus, managing fatigue-related risk is about understanding the sources of fatigue and how they may impact within a given work context. Evidence indicates that sleepiness, reduced alertness, impaired performance and errors do occur in the rail industry and that fatigue is a contributing factor. The management of fatigue-related risk requires a layered system of defences, one of which is working hours, but it also goes beyond hours to include other organisational, team and individual controls.

B Incident investigation

Where fatigue is suspected as being a contributory factor to a safety-related occurrence, the collection and analysis of the following information may help establish if this is the case:

- Time of day of accident (consider circadian rhythms – did the accident occur during a period of high or low alertness);
- Time on task, time on duty, type of task;
- Work history (e.g. time elapsed since last worked, and amount of wakefulness prior to the occurrence etc.)
- Date and time of event
- Planned hours of work over the last 2 week period
- Actual hours over the last 2 week period
- Sleep history of the individual(s)
- How many hours of sleep did the person(s) get in the preceding 24 and 48 hours?
- Have their sleep patterns involved poor, average or above average quality of sleep (Trap work and non-work related fatigue issues)?
- How long is their commute time?
- Were signs or symptoms of fatigue evident prior to the event?
- If available, any documented or self-reported medical history of sleep disorders or issues (e.g. sleep apnoea or insomnia); and
- Work conditions that have the potential to increase or decrease feelings of fatigue: for example: temperature, humidity and other weather conditions

C Tools that can assist in identifying increased likelihood of fatigue (proactively, presently and retrospectively) and assist in evaluating current controls.

Tool	Description	Benefits	Considerations
Hours of work rules	Pre-determined limits set for work hours dimensions such as shift duration, maximum hours worked in 7 days, number of rest days, maximum night hours worked in 7 days, maximum number of consecutive shifts etc	Effective as a starting point for the generation of safe rosters and schedules. Can be looked at in advance of the roster being worked. Can be used to assist in the analysis of the base roster (rostered hours) in terms of fatigue likelihood as well as the day-to-day assessment (actual hours worked)	Problematic if used in isolation as they assume that if the 'rules' are followed then all employees will report 'fit-for-duty'. Limiting work hours does not assure that people will obtain adequate sleep Day-to-day monitoring requires individuals and/or supervisors to report when work hours are unexpectedly changed.
Bio-mathematical models	Most models aim to estimate work-related fatigue based on a number of factors input into the model – these can include; duration and timing of work periods, number of consecutive rostered periods, rest periods, actual sleep. There needs to be systematic and scientific basis for assigning fatigue threshold cut-offs across actual work schedules and employees utilizing modeling software need to receive appropriate training.	Effective way of estimating fatigue associated with a work pattern and estimating how fatigue is distributed among people or business units. Allows comparison of different rosters in terms of fatigue risk. Can be used well in advance of the roster being worked. Can complement rostering practices	Problematic if used in isolation as they assume that if the 'rules' are followed then all employees will report 'fit-for-duty'. Does not account for emergencies, overtime, roster changes, having a sleep disorder, actual sleep obtained, individual differences or what happens during non-work time that may contribute to fatigue. Not a substitute for a well thought out and comprehensive FRMP. Models assume that sleep is obtained in the time between shifts. Organisations need to have a clear understanding of how the model works including how to interpret results and be aware of any limitations.
Individual sleep/wake assessments	Individuals can ask questions about their own sleep and wake to perform informal self-assessments. 'How long have I been awake?' 'How long will I have been awake by the end of my shift?' 'How much sleep have I had in the previous 24h, 48h, 72h'?. The beginning of a shift can be the trigger for these questions. Can be a personal assessment, verbal assessment to a supervisor or recorded in a fatigue-log or similar.	Scientific evidence linked to both lack of sleep and extended wake and performance degradation. Cut offs for increased likelihood of fatigue in terms of prior sleep and wake are supported by literature	Relies on the individual or a supervisor to monitor and to ask the questions in the first instance. Time will need to be allocated if data is to be recorded and then collated and used as part of the FRMP.

Prior Sleep Wake Model	A model that involves a calculation using a formula based on prior sleep and wake (Dawson & McCulloch, 2005). A value is generated and corresponds to a level of fatigue risk (e.g. moderate, high, very high) each of which will be assigned a pre-determined course of action as determined by the organisation.	Reasonably easy to administer, requires some calculation depending on mode of delivery. Educational value in the use of this type of model or the individual sleep wake assessment questions.	Requires a trigger to initiate calculation (e.g. supervisor initiated, start of shift, start of night shift). Time will need to be allocated if data is to be recorded and then collated and used as part of the FRMP. Problematic if used in isolation. No evaluations done to date. Organisations need to evaluate cost/benefit based on current considerations. Requires strong positive culture in the organisation such that honest reporting is encouraged and dealt with in a positive manner.
Activity monitors	Objective sleep/wake assessments using movement and rest as indicators of wake and sleep. Validated against gold standard lab-based sleep recording.	Data can be used to examine actual sleep provided by a given work schedule. Very useful personal information for employees about their sleep patterns.	Not particularly cheap, not all those on the market have been validated and often requires external provider to manage collection and analysis of data.
Sleep Diaries	A structured document where individuals can record sleep times as well as document sleep quality etc. in association with particular work patterns	Can be collated and used to determine which particular shifts or shift patterns are associated with the poorest sleep and may require modification or the implementation of additional risk mitigation strategies.	Requires individuals to remember to complete the diaries Time will need to be allocated if data is to be collated and used as part of the FRMP. Benefits to the employees need to be clear and real to ensure engagement and trust.
Subjective symptom list	A simple list of possible symptoms that someone might exhibit when fatigued. An initial list is unlikely to be exhaustive and fatigue may manifest very differently in different people. Individuals need to be educated and encouraged to understand how they change when fatigued.	Quick and easy to administer. Can be used by supervisors and employees.	Requires a trigger to initiate symptom monitoring (e.g. supervisor initiated, start of shift, start of night shift). If information is to be used and fed back into the FRMP, needs to be recorded, collated and interpreted.
Self-reports for fatigue (e.g. Are U OK?)	A procedure which encourages workers to report to supervisors or team-mates when they are feeling fatigued.	Individuals are capable of assessing their own fatigue levels, often before objective signs are obvious to others. Fatigue reports can inform the development or implementation of additional fatigue management controls where fatigue likelihood is known to be increased (e.g. certain times of a roster cycle, as a result of workload, where rest	Individuals may not report elevated fatigue due to fear of reprisal, letting team-mates down, or not being well-informed about their personal symptoms. Self reporting of fatigue can be manipulated by less scrupulous individuals. While individuals can recognise signs of fatigue and sleepiness in themselves, at higher levels of fatigue, their ability to judge the degree to which their performance may be impaired is less accurate.

		accommodation is not optimised for quality sleep etc)	Further, fatigued individuals are less able to detect impending sleep onset.
Fatigue or sleepiness scales	Scientifically validated scales that assess fatigue or sleepiness e.g. Samn-Perelli Fatigue Checklist (Samn and Perelli, 1982). An appropriate action for each possible score needs to be pre-determined.	Quick and easy to complete.	Requires a trigger to initiate completion of the scale(s) (e.g. supervisor initiated, start of shift, start of night shift). If information is to be used and fed back into the FRMP, needs to be recorded, collated and interpreted.

D Symptom Checklist

The symptoms listed below are indicative of fatigue. While they may also be caused by factors other than fatigue, this list can still be used to assess potential impairment due to fatigue.

Potential Indicators of fatigue:	
• Eyes go out of focus / close for a moment	• Heavy and burning eyes
• Slowed, blurred vision	• Headaches and stomach aches
• Blurred vision	• Drowsy
• Wandering and disconnected thoughts	• Inattention to minor, but potentially important details
• Can't stop yawning	• Reduced morale and motivation
• Head nodding	• Degraded mental abilities (including memory, decision-making and perception)
• Forgetting to communicate with crew	• Increased distractibility and irritability
• Incorrect reading of equipment	• Reluctance to initiate tasks and take command
• Forgetting check points	• Reduced sense of humour
• Missing reference points	• Tendency to exaggerate
• Can't remember last command given	• Tendency to take unnecessary risks
• Missing radio calls / vigilance	• Slowed reaction time
• Giving the wrong information	• Increased errors and tolerance for errors
• Difficulty concentrating	

E References

Akerstedt T. (1995). Work hours, sleepiness and accidents. Introduction and summary. Journal of Sleep Research 4: 1-3.

Akerstedt T. (1998a). Is there an optimal sleep-wake pattern in shift work? Scan J Work Environ Health 24(Suppl 3): 18-27.

Akerstedt T. (1998b). Shift work and disturbed sleep/wakefulness. Sleep Med Rev 2: 117-128.

Akerstedt T and Gillberg M (1981). The circadian variation of experimentally displaced sleep. Sleep 4(2): 159-169.

Akerstedt T, Kecklund G and Knutsson A (1991). Spectral analysis of sleep electroencephalography in roating three-shift work. Scand J Work Environ Health 17: 330-336.

Akerstedt T and Torsvall L (1983). A questionnaire study of sleep/wake disturbances and irregular work hours. Sleep Res 12: 358.

Arnberg PW, Bennerhult O and Eberhardt JL (1990). Sleep disturbances caused by vibrations from heavy road traffic. J Acoustical Soc Amer 88(3): 1486-1493.

Aschoff J. (1965). Circadian rhythms in man. Science 148(3676): 1427-1432.

Basner M, Fomberstein KM, Razavi FM, Banks S, William JH, Rosa RR and Dinges DF (2008). American Time Use Survey: Sleep time and its relationship to waking activities. Sleep 30(9): 1085-1095

Baulk SD and Fletcher A (2012). At home and away: Measuring the sleep of Australian truck drivers. Acc Anal Prev 455: 36-40.

Baulk SD, Fletcher A,Kandelaars KJ, Dawson D and Roach GD (2009). A field study of sleep and fatigue in a regular rotating 12-h shift system. App Ergon 40(4): 694-698.

Baulk SD, Kandelaars KJ, Lamond N, Roach GD, Dawson D and Fletcher A (2007). Does variation in workload affect fatigue in a regular 12-hour shift system? Sleep Biol Rhythms 5: 74-77.

Baysari MT, McIntosh AS and Wilson JR(2008). Understanding the human factors contribution to railway accidents and incidents in Australia. Acc Anal Prev 40(5): 1750-1757.

Belenky G, Wesesten NJ, Thorne DR, Thomas ML, Sing H, Redmond DP, Russo MB and Balkin TJ (2003). Patterns of performance degradation and restoration during sleep restriction and subsequent recovery: a sleep dose-response study. J Sleep Res 12: 1-12.

Cabon P, Coblentz A, Mollard R and Fouillot JP (1993). Human vigilance in railway and long-haul flight operation. Ergon 36(9): 1019-1033.

Darwent D, Dawson D and Roach GD (2010). Prediction of probabilistic sleep distributions following tavel across multiple time zones. Sleep 33(2): 185-195.

Darwent D, Lamond N and Dawson D (2008). The sleep and performance of train drivers during an extended freight-haul operation. App Ergon 39: 614-622.

Darwent D, Roach GD and Dawson D (2012). How well do truck drivers sleep in cabin sleeper berths? App Ergon 43: 442-446.

Dawson D and McCulloch K (2005). Managing Fatigue: It's about sleep. Sleep Med Rev 9: 365-380.

Dawson D and Reid K (1997). Fatigue, alcohol and performance impairment. Nature 388: 235.

Dembe AE, Eriskon JB, Delbos RG, Banks SM (2005). The impact of overtime and long work hours on occupational injuries and ilnesses: new evidence from the United States. OEM 62: 588-597.

Di Milia L, Smolensky MH, Costa G, Howarth H, Ohayon M and Philip P (2011). Demographic factors, fatigue and driving accidentsL an examination of the published literature. Acc Anal Prev 43(2): 516-532.

Dijk D-J, Duffy JF and Czeisler CA (1992). Circadian and sleep/wake dependent aspects of subejctive alertness and cognitive perfroamnce. J Sleep Res 1: 112-117.

Dorrian J, Hussey F and Dawson D (2007a). Train Driving Efficiency and Safety: Examining the Cost of Fatigue. J Sleep Res 16(1): 1-11.

Dorrian J, Roach GD, Fletcher A and Dawson D (2007b). Simulated Train Driving: Fatigue, Self-Awareness and Cognitive Disengagement. App Ergon 38(2): 155-166.

Dorrian J, Sweeney M and Dawson D (2004). A Prior Sleep/Wake Model of Fatigue-Related Accident Risk in Truck Drivers. J Sleep Res 13(Suppl. 1): A194.

Driskell JE and Mullen B (2005). The efficacy of naps as a fatigue countermeasure: A meta-analytic integration. Human Factors 47: 360-377.

Drake CL, Roehrs T, Richardson G, Walsh JK, Roth T (2004). Shift work sleep disorder: prevalence and consequences beyond that of symptomatic day workers. Sleep 27(8): 1453-1462.

Edkins GD and CM Pollock (1997). The influence of sustained attention on railway accidents. Acc Anal Prev 29(4): 533-539.

Ferguson SA, Lamond N, Kandelaars KJ, Jay SM and Dawson D (2008). The impact of short, irregular sleep opportunities at sea on the alertness of marine pilots working extended hours. Chronobiol Int 25(2): 399-411.

Ferguson SA, Baker A, Lamond N, Kennaway DJ, Dawson D (2010). Sleep in a live-in mining operatoin: the influeuce of start times and restricted non-work activities. App Ergon 42(1): 71-75.

Ferrara M and De Gennaro L (2001). How much sleep do we need? Sleep Med Rev 5(2): 155-179.

Folkard S. (1997). Black times: temporal determinants of transport safety. Acc Anal Prev 29(4): 417-430.

Folkard S. (2008). Do permanent night workers show circadian adjustment? Chronobiol Int 25(2): 215-224.

Folkard S and Akerstedt T (2004). Trends in the risk of accidents and injuries and their implications for models of fatigue and performance. Av Space Environ Med 75(3): A161-A167.

Folkard S, Akerstedt T, Macdonald I, Tucker P and Spencer MB (1999). Beyond the three-process model of alertness: estimating phase, time on shift and successive night effects. J Biol Rhythms 14(6): 577-587.

Folkard S and Tucker P (2003). Shift work, safety and productivity. Occ Med 53(2): 95-101.

Gander P, Hartley L, Powell D, Cabon P, Hitchcock E, Mills A and Popkin S (2011). Fatigue risk management: Organizational factors at the regulatory and industry/company level. Acc Anal Prev 43(2): 573-590.

Hanecke K, Tiedemann A, Nachreiner F and Grzech-Sukalo H (1998). Accident risk as a function of hour at work and time of day as determined from accident data and exposure models for the German working population. Scand J Work Environ Health 24: 43-48.

Harma M, Tenkanen L, Sjoblom T, Alikoski T and Heinsalmi P (1998). Combined effects of shift work and life-style on the prevalence of insomnia, sleep deprivation and daytime sleepiness. Scand J Work Environ Health 24(4): 300-307.

Harma M, Sallinen M, Rante R, Mutanen P, Muller K(2002). The effect of an irregular shift system on sleepiness at work in train drivers and railway traffic controllers. J. Sleep Res. 11:141-151.

Ingre M, Kecklund G, Akerstedt T, Soderstrom M and Kecklund L (2008). Sleep length as a function of morning shift-start time in irregular shift schedules for train drivers: self-rated health and individual differences." Chronobiol Int 25(2): 349-358.

Jaehne A, Loessl B, Barkai Z, Riemann D and Hornyak M (2009). "Effects of nicotine on sleep during consumption, withdrawal and replacement therapy." Sleep Med Rev 13(5): 363-377.

Jay SM, Dawson D, Ferguson SA and Lamond N (2008). Driver fatigue during extended rail operations. App Ergon 39: 623-629.

Jay SM, Dawson D and Lamond N (2006). Train drivers' sleep quality and quantity during extended relay operations. Chronobiol Int 23(6): 1-12.

Jay SM, Petrilli RM, Ferguson SA, Dawson D and Lamond N (2006). The suitability of a caffeinated energy drink for night-shift workers. Physiol & Behav 87: 925-931.

Jewett ME, Wyatt JK, Ritz-de Cecco A, Khalsa B, Dijk D_J and Czeisler CA (1999). Time course of sleep inertia dissipation in human performance and alertness. J Sleep Res 8: 1-8.

Kandelaars KJ, Lamond N, Roach GD and Dawson D (2005). The impact of extended leave on sleep and alertness in the Australian rail industry. Ind Health 43: 105-113.

Knauth P, Landau K, Droge C, Schwitteck M, Widynski M and Rutenfranz J (1980). Duration of sleep depending on the type of shift work. Int Arch Occ Environ Health 46(2): 167-177.

Krauchi K and Wirz-Justice A (1994). Circadian rhythm of heat production, heart rate, and skin and core temperature under unmasking conditions in men. Am J Physiol 267(3): R819-829.

Lack L and Lushington K (1996). The rhythms of human sleep propensity and core body temperature. J Sleep Res 5(1): 1-11.

Lamond N, Darwent D and Dawson D (2005). "Train drivers' sleep and alertness during short relay operations." App Ergon 36: 313-318.

Lamond N and Dawson D (1999). Quantifying the performance impairment associated with fatigue. J Sleep Res 8: 255-262.

Lovato N, Lack L, Ferguson SA and Tremaine R (2009). "The effects of a 30-minute nap during night shift following a prophylactic sleep in the afternoon. Sleep Biol Rhythms 7: 34-42.

Lombardi DA, Folkard S, Willetts JL and Smith GS (2010). Daily sleep, weekly working hours and risk of work-related injury: US National Health Interview Survey (2004-2008). Chronobiol Int 27: 1013-1030.

Macchi MM, Boulos Z, Ranney T, Simmons L and Campbell SS (2002). "Effects of an afternoon nap on nighttime alertness and performance in long-haul drivers." Acc Anal Prev 34(6): 825-834.

Monk TH and Wagner J (1989). Social factors can outweigh biological ones in determining night shift safety. Human Factors 31: 721-724.

Moore-Ede M (2009). Evolution of fatigue risk maangement systems: The tipping point of employee fatigue mitigation. CIRCADIAN ® White Papers

Parkes KR (1994). Sleep patterns, shiftwork, and individual differences: a comparison of onshore and offshore control-room operators. Ergonomics 37: 827-844.

Pilcher JJ and Hufcutt AI (1996). Effects of sleep deprivation on performance: a meta-analysis. Sleep 19: 318-326.

Reason J. (1990). Human Error. New York, Cambridge University Press.

Reinach S. and Viale A (2006). Application of a human error framework to conduct train accident/incident investigations. Acc Anal Prev 38(2): 396-406.

Richter S, Marsalek K, Glatz C and Gundel A (2005). "Task-dependent differences in subjective fatigue scores." Journal of Sleep Research 14: 393-400.

Roach GD, Reid K and Dawson D (2003). The amount of sleep obtained by locomotive engineers: Effects of break duration and time of break onset. Occ Environ Med 60: e17.

Rosa R. (1995). Extended workshifts and excessive fatigue. J Sleep Res 4: 51-56.

Sallinen M, Harma M, Akerstedt T, Rosa RR and Lillqvist O (1998). Promoting alertness with a short nap during a night shift. J Sleep Res 7: 240-247.

Sallinen M, Harma M, Mutanen P, Ranta R, Virkkala J and Muller K (2003). Sleep-wake rhythm in an irregular shift system. J Sleep Res 12: 103-112.

Siebenaler MJ and McGovern PM (1991). Shiftwork: Consequences and considerations. 39: 558-567.

Smith L, Folkard S and Poole CJM (1994). Increased injuries on night shift. The Lancet 344: 1137-1139.

Smith L, Folkard S and Tucker P (1998). Work shift duration: a review comparing eight hour and 12 hour shift systems. Occ Env Med 55: 217-229.

Tepas D and Carvalhais A (1990). Sleep patterns of shiftworkers. Occupational Medicine State of the Art Reviews: Shiftwork. S. AJ. Philadelphia, Hanley & Belfus Inc. 5: 199-208.

Thomas GR. and Raslear TG (1997). The effects of work schedules on train handling performance and sleep of locomotive engineers: A simulator study. Washington, DC, USA, Department of Transportation, Federal Railroad Administration.

Thompson K, Rainbird S, Dawson D (2010). The nature of the beast: Metropolitan train drivers' experience, perception and recogntiion of fatigue. Living in a 24/7 world: The impact of circadian disruption on sleep, work and health. C Sargent, D Darwent and GD Roach. Adelaide, Australasian Chronobiology Society: 1-5.

Tucker P, Folkard S and Macdonald I (2003). "Rest breaks and accident risk." Lancet 361(9358): 680.

Tucker P, Macdonald I, Folkard S, Smith L (1998). The impact of early and late shift changeovers on sleep, health and well-being in 8- and 12-hour shift systems. J Occ Health Psychol 3(3): 265-275.

Van Dongen HPA, Maislin MA, Mullington JM and Dinges DF (2003). "The cumulative cost of additional wakefulness: Dose-response effects on neurobehavioural functions and sleep physiology from chronic sleep restriction and total sleep deprivation." Sleep 26(2): 117-126.

Wetterberg, L. (1994). "Light and biological rhythms." Journal of Internal Medicine 235(1): 5-19.

Williamson AM and Feyer A-M(2000). Moderate sleep deprivation produces impairments in cognitive and motor performance equivalent to legally prescribed levels of alcohol intoxication. Occ Environ Med 57: 649-655.

Williamson AM and Friswell R (2011). Investigating the relative effects of sleep deprivation and time of day on fatigue and performance. Acc Anal Prev 43: 690-697.

Zhou X, Ferguson SA, Matthews RW, Sargent C, Darwent D, Kennaway DJ and Roach GD (2010). "Interindividual differences in neurobehavioural performance in response to increasing homeostatic sleep pressure." Chronobiol Int 27(5): 922-933.

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