Fatigue Risk Management Guide

A guide to worker fatigue management among pipeline construction companies in North America

Prepared by Ulises Techera, PhD under the direction of The INGAA Foundation and a group of subject matter experts

EXECUTIVE SUMMARY

The last few decades of research have revealed the overwhelming negative effect of worker fatigue on accident causation, which affects the pipeline construction and operation industry. The INGAA Foundation has produced this guide to provide science-based knowledge and serve as a reliable resource for better managing worker fatigue in this industry. The guide presents principles for developing a Fatigue Risk Management System (FRMS), which constitutes the recommended way of managing fatigue in a work environment.

The guide is organized into ten sections. Section one introduces the reader to the document, indicating the purpose, scope, and the guide's intended audience. The second section defines worker fatigue and provides an overview of its characteristics. The third section describes the importance of obtaining sufficient sleep to recover from the effects of fatigue. Section four explains how to implement wellness and nutrition programs that can positively affect the workers' health and fatigue levels while section five establishes roles and responsibilities in managing fatigue. Then, sections six through eight present strategies to manage fatigue in this industry and information on how technology can aid in this endeavor. Lastly, the guide suggests how training should be conducted to guarantee continuous improvement.

The application of this guide will contribute to a safer pipeline industry.

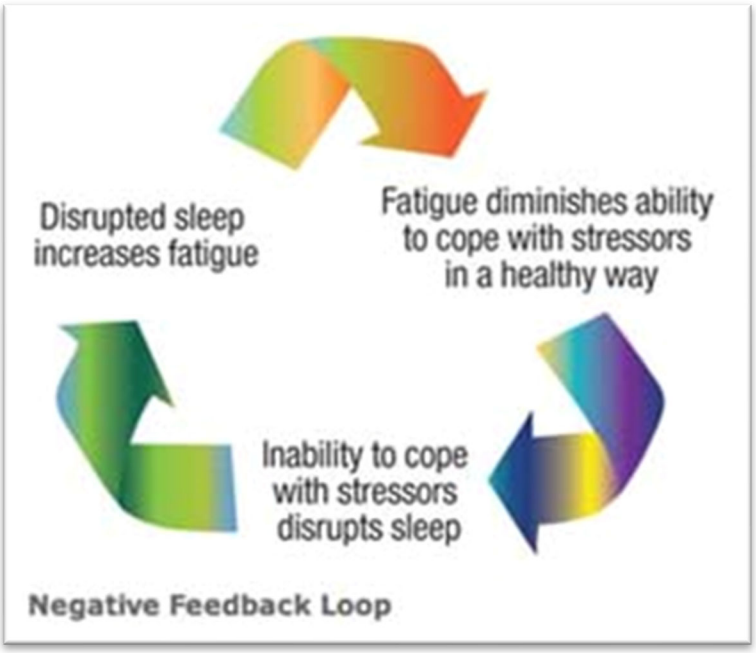
DISCLAIMER

The contents of this document are provided for informational purposes only, and it is subject to recurring review due to changing industry requirements and regulations. This document is not comprehensive, it does not constitute legal advice, and it must not be relied upon for any legal purpose. No subscriber or other reader should act based on any such information without referring to applicable laws, regulations, and professional advice. Despite all efforts to ensure accuracy, the INGAA Foundation and other contributors to this guide shall not be held responsible for any loss or damage caused by errors, omissions, misprints, or misinterpretation of the contents thereof. Furthermore, INGAA Foundation, and the contributors to this document expressly disclaim any and all liability to any person or entity, whether a purchaser of this publication or not, regarding anything done or omitted, and the consequences of anything done or omitted, by any such person or entity in reliance on the contents of this publication.

Opinions expressed in this publication do not necessarily reflect the opinion of INGAA Foundation or the contributors. The mention of specific companies, technologies, and products in this publication does not imply that they are endorsed or recommended by any of the above in preference to others of a similar nature that are not mentioned.

TABLE of CONTENTS

1. INTRODUCTION



The INGAA Foundation (Foundation) was formed in 1990 by the Interstate Natural Gas Association of America (INGAA) to facilitate the construction and operation of natural gas pipelines for the benefit of the consuming public and the natural gas industry. The Foundation is uniquely positioned as the forum to convene industry leaders who will develop and deliver safe, affordable, reliable, and clean energy solutions into the future through creative problem solving using networking and collaborative efforts, fostering individual and workforce development, and assuring that key industry decision makers are well-informed.[1]

Worker Fatigue has been identified in this sector as a significant contributing factor of accidents.[2] Fatigue causes cognitive and physical impairments that give place to inadequate communication and improper use of personal protective equipment and tools, thus leading to accidents. A more effective management of fatigue in the industry is paramount to improving safety.[1]

The purpose of this guide is to assist pipeline construction contractors in developing robust fatigue management policies and procedures. The most effective way of managing fatigue in the industry comes from the development of a Fatigue Risk Management System (FRMS). This document provides guidelines on how to develop an FRMS for the Pipeline Construction Industry and presents science-based fatigue risk management guidelines. These guidelines should be implemented to minimize incidents, serious injuries, and fatalities due to fatigue. Fatigued workers are less able to perform work safely and efficiently, which may pose a risk to themselves and others. This guide is intended to educate and empower the workforce to proactively identify fatigue symptoms and take appropriate action.

The guidelines in this document are not meant to supersede or replace regulatory requirements, nor are they intended to be all-inclusive of the applicable contractor/owner company safety protocols or regulatory requirements. Instead, these guidelines are intended to support and complement existing requirements and provide actionable solutions to meet them.

This guide is intended to be used by those involved in the planning and execution of pipeline construction, including but not limited to:

- Company upper-level management and administrators
- Company mid-level managers, safety managers, supervisors, team leaders and superintendents
- Construction crew foremen, front-line workers, and subcontractors
- Regulators, practitioners, trainers, and human resources personnel

Given the importance of addressing fatigue in the Pipeline Construction Industry, a team of Subject Matter Experts (SMEs) and Industry Practitioners was assembled by the INGAA Foundation to examine the existing body of knowledge and synthesize a practical set of guidelines to better manage fatigue in this sector. The guide is not intended to be exhaustive, and the application of the principles presented in this document may vary according to local characteristics. An FRMS should be an integral part of and developed in the context of a Safety Management System (SMS). A diverse team with people representing each level of an organization should engage in the development of a company specific FRMS. This team should examine the fatigue management principles presented in this document and develop fatigue management plans (FMP) and policies that are both applicable and tenable as part of their FRMS.

ACKNOWLEDGEMENTS

The INGAA Foundation commissioned this Fatigue Risk Management Guide in consultation with stakeholders from member organizations and subject matter experts, who have worked together to produce the content of this guide. INGAA Foundation would like to thank the following for their assistance in the development of this document:

1. Steering Committee and Contributors
    a. Chris Rhudy, *Southland Safety, Committee Chair*
    b. Chris Smith, *Cheniere*
    c. Brian Seaman, *Kinder Morgan*
    d. Zach Bowler, *Barnard Pipeline, Inc*
    e. Kevin Parker, *Mears Group*
    f. Jason Leger, *Sunland Construction, Inc.*
    g. Victor Flores, *TC Energy*
2. Subject Matter Experts
    a. Dr. Ulises Techera, *TECHERA LLC*
    b. Beth Sims, *WGA*
    c. Coralie Crawford, *Price Gregory International*
3. Technical Writer
    a. TECHERA LLC

ACRONYMS AND DEFINITIONS

Term	Definition / Usage
Acute Fatigue	Fatigue lasting less than one month
Call Out	Summoning an employee to the work site to perform work that was not scheduled
Chronic Fatigue	Fatigue lasting one to six months or longer
Cognitive Fixation	A symptom of excessive fatigue where the individual will focus on some specific detail to the exclusion of their attention on other possibly important information or events
Cumulative Fatigue	The increase in fatigue over consecutive sleep/wake periods resulting from inadequate rest
Extended Shifts	Work shifts that extend outside the regularly scheduled shift hours
Fatigue	The state of impaired mental and/or physical performance and lowered alertness arising from intense work in combination with insufficient recovery
FHA	Fatigue Hazard Assessment
FLHA	Field Level Hazard Assessment
FLRA	Field Level Risk Assessment
FMP	Fatigue Management Plan
FRMS	Fatigue Risk Management System
JSA	Job Safety Analysis
Normal Operations	Operations that are not during outages or extended shifts
Outages	Planned or unplanned interruption in the normal operations of a unit or plant
PTRA	Pre-Task Risk Assessment
SMS	Safety Management System
SSSP	Site Specific Safety Plan
Work Sets	Consecutive shifts with a minimum period off before starting another work set

2. FATIGUE OVERVIEW

Fatigue affects more than 20% of workers daily, especially those involved in heavy manual labor and shift work like pipeline construction workers. Occupational fatigue presents as extreme tiredness and a diminished ability to perform work tasks.[3]

Fatigue is a state of impaired mental and/or physical performance and lowered alertness arising from intense work in combination with insufficient recovery (i.e. sleep). Lack of sleep and irregular sleeping habits impair a worker's recovery, thus prolonging the effects of fatigue.[3]

The risk of fatigue is inherent to any job involving long working hours, irregular shifts, night shifts, and physically or mentally demanding work, all of which are present in pipeline construction. Fatigue is also influenced by an individual's health and wellness, diet, drug and alcohol intake, emotional well-being, and work environment conditions.[3]

MAIN CAUSES OF WORKER FATIGUE[3]

- Sleep deprivation and lack of recovery
- Mental exertion
- Muscular exertion
- Heavy workload
- At work environmental factors (noise, light, vibration, temperature, etc.)
- Long shifts and overtime
- Social work-environment
- Emotional predisposition or distress

MAIN SYMPTOMS OF WORKER FATIGUE[3,4]

- Feeling tired or unable to do things at the usual pace
- Feeling unmotivated and sad
- Moving slower
- Making a greater number of mistakes
- Feeling without energy or sleepy

- Being distracted, forgetful, and having problems to execute work tasks
- Feeling weaker
- Rushing up to finish a job

MAIN WORKER FATIGUE CONSEQUENCES[3]

- **Cognitive Degradation:** Fatigue significantly affects cognitive functions, both complex and basic. Some of the complex cognitive functions greatly affected by fatigue include the ability to comprehend and communicate, planning and making decisions, and creative thinking.[5,6] Some of the basic cognitive functions affected by fatigue include concentration and attention. [7–9]
- **Reduced Reaction Time:** Reacting to a stimulus is essential to be safe in a hazardous environment. Fatigue can greatly slow a person's reaction time; for example, a fatigued individual's reaction time may be between 24% and 57% slower than a well-rested person's.[10–12]
- **Physical Degradation:** Johnston et al. (1998) found that fatigue negatively affects workers' static and dynamic balance, making them more prone to fall (principal fatal four accidents in construction). Additionally, fatigue reduces muscular strength. This, combined with a slower reaction time, usually leads to more errors.[13,14]
- **Negative Mood Changes:** Fatigue can quickly induce feelings of depression and sadness, which not only makes work more difficult between coworkers but also decreases complex cognitive performance and the ability to perceive risk.[15] Mood changes induced by long term fatigue can also lead to anxiety.[6,16–22]
- **Error and Injuries:** Given the consequences of fatigue previously mentioned, it is easy to see how fatigue contributes to a greater number of errors, which, in a hazardous environment, usually lead to accidents.[23–26]
- **Illnesses:** Long-term exposure to fatigue on a regular basis, induced by circadian rhythm misalignment, can give place to gastrointestinal disorders, such as constipation and diarrhea, bowel pain, and even ulcers [22,27,28]; and cardiovascular diseases.[29,30] Additionally, fatigue has shown to negatively affect pregnancy and diabetes.[27,31]

GENERAL WORKER FATIGUE PREVENTION STRATEGIES

The use of coffee and energy drinks to counteract fatigue, while common, represents a dangerous and short-term palliative resource that can have dire consequences on workers' health.

Fatigue Prevention Strategies[3,4]

- Sleep approximately 8hs in-between shifts
- Take regular breaks at work
- Eat healthy snacks
- Take a power nap
- Pace yourself while working
- Hydrate
- Take some fresh air
- Ensure appropriate work environmental conditions

3. SLEEP and FATIGUE

Sleep is the most restorative activity to eliminate worker fatigue. Conversely, the lack of sleep impairs fatigue recovery and workers' performance. Most adults need between 7 and 8 hours of sleep to feel well-rested. Several studies demonstrate that sleeping one hour less than the recommended amount can cause up to a 10% decrease in cognitive performance. Furthermore, a single night of sleep deprivation can cause up to 30% cognitive impairment, and this effect compounds with consecutive sleepless nights. However, cognitive degradation is just one of the many negative consequences of sleep deprivation.[13,32,33]

Sleep can be affected by circadian misalignment or several sleep disorders, in this section we will introduce you to these and increase your awareness of their effect.

CIRCADIAN RHYTHM MISALIGNMENT

Human beings present an internal clock, denominated endogenous circadian rhythm, with a period of approximately 24 hours that determines when a person should be asleep or awake.[34] Such a circadian rhythm can be tracked by two main physiological variables: core body temperature and endogenous melatonin (EM) concentration; sleep follows the EM pattern.[35] Please, see Figure 1 for a graphical representation of these variables. Figure adapted from Bjorvatn and Pallesen (2009). [35]

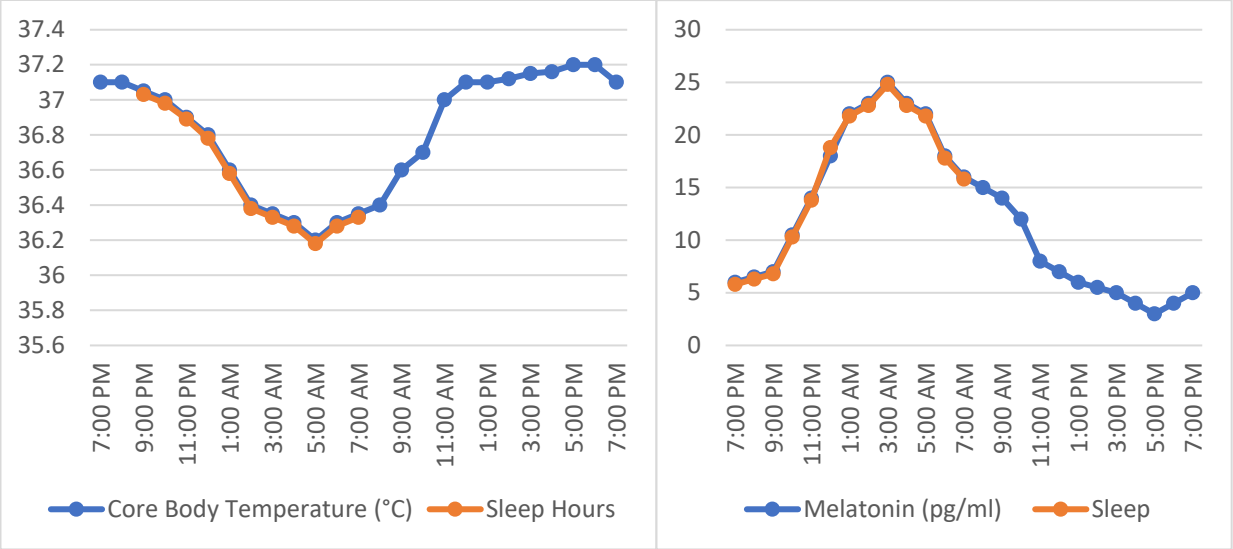


Figure 1: Core Body Temperature - Melatonin and Sleep

Causes: Circadian disorders are caused by a misalignment between the endogenous circadian rhythm in a person's routine requirement. Between 19% and 30% of the working population operate in a shift that obligates them to get up too early, go to bed too late, or work through the night.[36] Night shift workers present the worst statistics, with 3% adapting entirely to the night shift, less than 25% of them experiencing some adaptation, and over 72% presenting no adaptation at all.[37]

In general, irregular shifts create a misalignment between the internal circadian rhythm and the external environmental factor, thus changing the time when adults usually go to bed. As a result, such individuals experience a shorter sleep period and consequent incomplete recovery (accumulation of fatigue).[38] Additionally, suppose the worker attempts to manage sleepiness and fatigue by napping. In that case, the immediate effect will likely be positive. However, it may have a negative impact in the longer term by diminishing the time they are awake (homeostatic process) and thus reducing the quality of sleep during the following sleep period (less slow-wave activity).[39] As a result, shift work can induce a circadian rhythm misalignment that is difficult to overcome and that negatively affects safety and health.

Consequences: Circadian disorders can cause a plethora of negative consequences. Perhaps the most noticeable effects are related to the sleepiness and fatigue caused by such a disorder, which can, in turn, produce decreased alertness and cognitive impairment that give place to a higher rate of errors, accidents, and fatalities.[3] Furthermore, the hormonal changes associated with a circadian disorder can also give place to reproductive, cardiovascular, and gastrointestinal health problems and even cancer.[40,41]

Prevention: While different treatments are effective in advancing or retarding the internal circadian rhythm of an individual to make it match the external 24-hour cycle, research suggests that these types of solutions are temporary and that if applied long term, they may cause negative consequences. For instance, timed bright light administered before the lowest point in the core body temperature curve can delay the circadian rhythm during night work, keep workers alert during early morning hours, and move the minimum core body temperature to a later time. However, this approach may cause safety issues outside of work, for example, causing the worker to fall asleep while driving back home. The intake of melatonin may also be an alternative to alleviate the effects of shift work, considering that when

administered in the late afternoon or evening, it will advance the circadian phase, helping workers reach sleepiness earlier. When administered in the morning, it will delay the circadian phase, allowing workers to conceive sleep in the morning which in turn prevents them from achieving sleep at night. Appropriate melatonin administration is about 12 hours after bright light (when needed).[35] Both of these therapies, when administered long-term, may increase the risk of cancer and ocular damage.[42] Consequently, the most appropriate way of minimizing the risks associated with circadian misalignment may be to avoid this misalignment when possible. Additionally, implementing predictive technologies able to detect risky situations with lead time (e.g., reaching dangerous fatigue levels) and fatigue-proofing the work environment would contribute to preventing severe injuries and fatalities.

SLEEP APNEA

"Sleep apnea is a common condition in which your breathing stops and restarts many times while you sleep. This can prevent your body from getting enough oxygen." "Obstructive Sleep Apnea (OSA) is the most common type of sleep apnea and happens when your upper airway becomes blocked many times while you sleep, reducing or completely stopping airflow." "Central sleep apnea (CSA) happens when your brain does not send the signals needed to breathe. Health conditions that affect how your brain controls your airway and chest muscles can cause central sleep apnea."[43]

Causes: Anything that could narrow your airway could give place to OSA. When the soft tissue muscles in your throat relax, your airway narrows or closes, and your ability to breathe is compromised. When your brain senses your inability to breathe, it awakes you so that you can reposition and reopen your airway. This awakening is usually so brief that you don't remember it. However, it can occur 30 or more times an hour, preventing you from reaching truly restorative sleep. CSA, on the other hand, is caused by a compromised brainstem, unable to send signals through the spinal cord to your breathing muscles.[44]

Consequences: While sleeping, people with sleep apnea usually snore, wake up often, experience gasping and choking, teeth clenching and grinding, or parasomnias (sleep disorders involving physical events such as sleep walking or night terrors). During the waking hours, they experience brain fog, sleepiness, jaw pain, headaches, and nasal congestion. Sleep apnea can also compound other illnesses associated with cardiovascular conditions, diabetes, cancer, and dental health.[44]

Prevention: OSA can result from obesity, large tonsils, or changes in hormone levels. CSA can result from a congenital disorder, an accident, or the effects of another medical condition. Sometimes surgery can help prevent sleep apnea.[43,44] Persons suffering from the symptoms described should seek medical attention.

INSOMNIA

Insomnia is "a common sleep disorder that can make it hard to fall asleep, hard to stay asleep, or cause you to wake up too early and not be able to get back to sleep." As a result of insomnia, it is common to feel tired after a night of rest and weak throughout the workday. This condition can also affect your mood, performance, health, and overall quality of life.[45]

Stress or traumatic events can sometimes cause short-term insomnia (lasting from a couple of days to a few weeks). Up to 35% of people occasionally experience it for a short period, which doesn't constitute a

sleep disorder. However, when this phenomenon extends for a month or longer, the worker should address insomnia with a medical provider, as this could represent the development of a sleep disorder.[45]

Insomnia Symptoms [45]

- Difficulty falling asleep
- Waking up during the night
- Irritability, depression, or anxiety
- Lack of memory and difficulty paying attention and focusing
- Not feeling well rested
- Getting up too early
- Sleepiness and fatigue during the day
- Errors and accidents

Causes: While workers may experience a physiological condition that directly affects their ability to sleep, often, insomnia has another origin, such as stress, bad health, nightshifts, and poor habits. Work, school, health, finances, relationships, and loved ones can be the source of worries that make it difficult to relax the mind and achieve adequate sleep. Disrupting the circadian rhythm due to night or rotating shifts can also give place to insomnia. Mental health disorders, medication, medical conditions, and caffeine intake also impact our ability to sleep. Lastly, poor habits such as an irregular bedtime schedule, screen time (cellphone, TV, etc.) late at night, or overeating before going to bed can also produce insomnia.[45]

Consequences: Recovery through sleep is a vital need of the human body; not satisfying it will certainly lead to mental and/or physical disorders. People with insomnia usually report a lower quality of life, as they perform sub optimally at work and school, are more prone to mental health disorders and substance abuse, present a slower reaction time, and experience more accidents.[45,46]

Prevention: Prioritizing wellness and developing good sleep hygiene will help you sleep better. Maintaining an active lifestyle with regular exercise, a healthy diet, and eating at appropriate times will positively affect your ability to fall asleep and rest. Creating an environment conducive to falling asleep and going to bed at a consistent time will also help you obtain quality sleep.[45,46]

NARCOLEPSY

This condition "is a chronic sleep disorder characterized by excessive daytime sleepiness (EDS) and sudden attacks of sleep." "Even with an appropriate amount of rest, people with narcolepsy often find it hard to stay awake for extended periods." Narcolepsy can seriously impact an individual's routine and ability to work and study. While there is not a known cure for narcolepsy yet, medications and lifestyle changes can help manage its consequences.[47]

Causes: There are two types of narcolepsy: type 1 (NT1) and type 2 (NT2). NT1 presents sudden loss of muscle tone while experiencing intense emotions. Narcolepsy presents autoimmune and genetic components, but the exact cause of narcolepsy is unknown. However, people with NT1 have low levels of hypocretin, a brain chemical that controls being awake and entering rapid eye movement (REM) sleep.[47] Narcolepsy without muscle tone loss is known as Type 2.

Consequences: Some of the most common symptoms of narcolepsy include excessive daytime sleepiness, sudden loss of muscle tone, the temporary inability to move while falling asleep or waking up,

hallucinations, and quickly falling into rapid eye movement (REM) sleep at night or during the day. People with narcolepsy often develop obesity. If a worker experiences some of these symptoms, they should consult a medical provider soon as diagnosing narcolepsy can be tricky.[47]

Prevention: There are no known prevention strategies; however, knowing the risk factors can help you seek treatment sooner. Narcolepsy is usually developed between the ages of 10 and 30, and you are up to 40 times more likely to experience it if a close relative has it.[47]

4. NUTRITION, WELLNESS, and FATIGUE

Our diet impacts our hormones, neurotransmitters, sleep cycles, mood, and can also affect our stamina and fatigue levels. Being on the road and in remote locations due to work can affect a worker's diet. Consuming grains, refined carbohydrates, and sugary foods in excess can lead to feeling fatigued. Avoiding the excessive consumption of carbohydrates and developing a diet based on healthy fats, proteins, vegetables, and essential nutrients will provide the long-term energy required throughout the workday.[48]

A good diet, with a significant number of meals with vitamin B and high in calcium, magnesium, selenium, and zinc, can provide you with a lasting energy source. High-sugar foods produce a "sugar high" followed by "lows" that make you more prone to experiencing fatigue. Processed and refined flours are quickly processed by the body into sugars, thus causing a similar effect. Furthermore, this last group of foods can cause intestinal inflammation, producing cortisol and leptin, leaving people weak and fatigued. Excessive caffeine can produce sleep disorders, which, in the long run, negatively impact your ability to recover from fatigue. Alcohol may help you fall asleep; however, it interferes with your ability to obtain REM sleep, which constitutes the most restorative sleep. Consequently, a worker should avoid the foods and drinks that induce fatigue.[48]

Because of the busy lifestyles that we lead, it is common for many people to develop a sedentary lifestyle, which can cause fatigue. Sitting all day is very hard on your body and often causes soreness, pain in your neck, stiffness, back pain, and chronic headaches. An unenergetic lifestyle causes fatigue, making you feel like you're always tired. Your body was made to move, so when it doesn't get regular activity you can experience mood issues, sluggishness, tiredness, and weight gain. Physical activity sends oxygen and nutrients to your body's cells, helping your heart and lungs work more efficiently and boosting energy levels.[48]

Understanding how daily lifestyle and diet affects a worker's wellness and wellbeing takes understanding & consideration of your culture. Using the positive aspects and attributes already present within the industry to accomplish change is crucial for new wellness practices to be accepted and become part of your existing culture.

Key areas of understanding of your audience

- Culture
- Resistance to change
- Lack of Education relating to healthier lifestyles
- Environment
- Continuous Support

Key areas of understanding when delivering the message

- Balance & Moderation
- Being able to distinguish between evidence-based nutritional information & unsupported claims
- Being adaptable regarding information and plan - One size does not fit all!
- Understanding the relationship between physical activity and health
- Being a resource
- Continuous awareness and education
- Address the What, Why & How
- Keep the message simple and encouraging
- Consistency and sincerity
- Understanding your culture is key to the successful creation, implementation, and adoption of wellness programs that generate wellbeing.

Ways to introduce wellness and wellbeing into the pipeline industry

- Orientation - Creating a separate orientation and handouts geared towards wellness, movement, and diet so that we are educating at the initial contact and then continued follow up with monthly posters, incentives either for individuals or groups.
- Toolbox discussions at the morning Job Safety Assessments (JSA)
- Monthly posters geared towards movement, nutrition, and lifestyle to effectively convey a message
- Design posters that are eye-catching and fun.
- Include images and humor unique to the culture.
- Keeping the message simple is the key to getting your message across.
- Use fun, realistic, and helpful ideas that are geared towards the workers' environment and culture.

5. FATIGUE MANAGEMENT ROLES and RESPONSIBILITIES

Every individual has a role to play in ensuring the effective management of fatigue so that work can be done in a safe, efficient, and productive manner.

Senior management responsibilities

- Implement, communicate, and support fatigue management on all job sites
- Demand that working hours for each project are determined considering fatigue risk factors
- Provide adequate resources to enable compliance with this guide
- Ensure that overtime requests are assessed considering fatigue risk factors
- Require adequate brakes in between shifts for workers transferring from other projects
- Guarantee the assessment of fatigue risk for each project
- Promote, support the development of, and approve a Fatigue Risk Management Plan (FRMP) for each project

FIELD SUPERVISOR RESPONSIBILITIES

Field Supervisor responsibilities apply to all personnel on site with a supervisory role.

- Schedule and plan work to mitigate fatigue by providing adequate time for individuals to sleep, rest, and recover between work periods and changes of shift rotations

- Show commitment to the fatigue management process by leading the development and sharing of the Fatigue Hazard Assessment (FHA), JSA's, and other applicable tools, including actions to confirm that:
  - The scope of work is reviewed thoroughly
  - All fatigue hazards are identified, analyzed, and captured in the risk matrix
  - The fatigue hazards are mitigated or managed
  - Hazard and control information is shared with everyone who will be on the site
  - All who review the hazard assessments, JSA's, and other documents supporting the scope of work have a means to give feedback
- Review the FHA, Site Specific Safety Plan (SSSP), JSA's, and all other applicable supporting documents to ensure that all fatigue hazards are identified, communicated, and addressed per the approved processes
- Ensure employees are 'fit' for work, monitor co-workers and team members for the signs and symptoms of fatigue, and monitor working hours
- Empower applicable (or authorized) personnel with the ability to mitigate or make recommendations on appropriate control measures for potential fatigue hazards
- Ensure that on-site personnel have reviewed and understand all applicable fatigue management guidelines
- Ensure that workers under their supervision are aware of and comply with the site-specific fatigue management measures
- Perform fatigue risk assessments
- Monitor fatigue risks and, when appropriate, carry out corrective actions
- Maintain records
- Ensure additional work hours are approved when necessary
- Perform objective assessments on the quality of preparation and communication of all fatigue management guidance

HEALTH AND SAFETY PERSONNEL RESPONSIBILITIES

- Confirm employees are trained in fatigue risks and their consequences
- Assist with developing Fatigue Risk Assessment Tools and the FMP, and all other applicable supporting documents
- Monitor compliance with this FMP and provide advice when necessary
- Conduct periodic inspections to ensure the requirements of the FMP are being met and the controls are effective
- Perform periodic audits of the hazard assessment, SSSP, JSA's, and all other applicable supporting documents to ensure proper application of fatigue management processes
- Review procedures to identify fatigue hazards
- Ensure fatigue as a risk factor is incorporated during all incident investigations
- Report, document, and conduct investigations into all fatigue related incidents

FRONT LINE WORKER RESPONSIBILITIES

Employees have responsibilities to comply with the FMP for their own safety and the safety of those around them.

Responsibilities include:

- Take regular breaks in the normal course of duties to ensure recovery
- Make every effort to get the restorative rest needed during periods away from work
- Incorporate adequate consideration of fatigue as a risk factor while making travel and commuting plans for each project
- Recognize and report signs of fatigue that could place the health, safety, and well-being of themselves or others at risk
- Immediately notify their supervisor of any unsafe conditions or actions that could endanger themselves or others
- Comply with plans and schedules
- Maintain records where required
- Cease work if they have reasonable belief that to continue could cause them or others harm
- Discuss with their prescribing medical practitioner the nature of their duties to identify any potential side effects of their medications that may impact their safety or performance at work and notify their Site Manager/Supervisor accordingly
- Take medication as directed and do not chronically use over-the-counter or prescription drugs or substances to increase mental alertness or induce sleep

6. KEY ELEMENTS TO MANAGE FATIGUE

STRUCTURE AND DESIGN OF WORK TIME ARRANGEMENTS

As part of the planning process, the structure of work activities and work time arrangements should be considered to minimize the potential of fatigue. Resources should be considered to ensure adequate rest periods.

Besides the required time to complete work activities, the establishment of work hours should consider:

- Travel to and from the jobsites
- A person's circadian rhythm
- The total number of hours worked in consecutive shifts
- Seasonal influences (heat, humidity, cold, rain, daylight hours, etc.)

There are several main principles that should be considered when planning work time arrangements:

- Work hours should be in accordance with Contract Award, Contract of Employment, or Enterprise Agreement Requirements with an allowance for reasonable overtime
- Allow seven to eight consecutive hours of sleep every 24 hours
- Plan for routine breaks while driving, total driving time in a day should be factored into the schedule and monitored by management
- Any required work over 12 hours should be infrequent and only approved when other options have been exhausted or additional controls have been implemented
- Plan for extreme / emergency situations, resources in an emergency may be limited, so managers must be extra vigilant in monitoring fatigue during emergency situations

Call-Outs

Because call-outs involve unpredictable patterns of work and rest, attention should be given to call-out practices to ensure adequate rest prior to returning to work.

The following factors should be considered:

- Call-outs during nocturnal hours will likely result in sleep disruption .

- Multiple call-outs during a day may provide little opportunity for consolidated, restorative sleep.
- Call-outs occurring on the day prior to or immediately after a work set may contribute to cumulative sleep debt .
- Call-outs that end shortly before the next scheduled shift, or shortly after a shift, effectively result in extended shifts, and should conform to those guidelines.
- Where on-call activity results in a significant break in the individual's sleep, the individual should not return to their routine until they have adequately rested.

At Work Supervisor Support

Strategies to address potential consequences of fatigue include but are not limited to the following:

- Management will support any employee who decides to stop working and report to management when fatigued (without any penalty being imposed on them).
- An individual who reports to work feeling tired or has not had sufficient consecutive hours of sleep prior to commencing work is encouraged to inform their immediate supervisor.
- Supervisors shall periodically monitor workers to look for symptoms of fatigue that compromise health and safety. If such symptoms are identified, the supervisor should offer or request a break from such an individual.
- Monitor accident and incident reports for fatigue-related issues (review and investigate as required)

Work Environment

Work conditions should help individuals to remain alert. Management has a responsibility to provide facilities that preserve workers health, safety, and comfort. Principles for providing such facilities include, but are not limited to, the following:

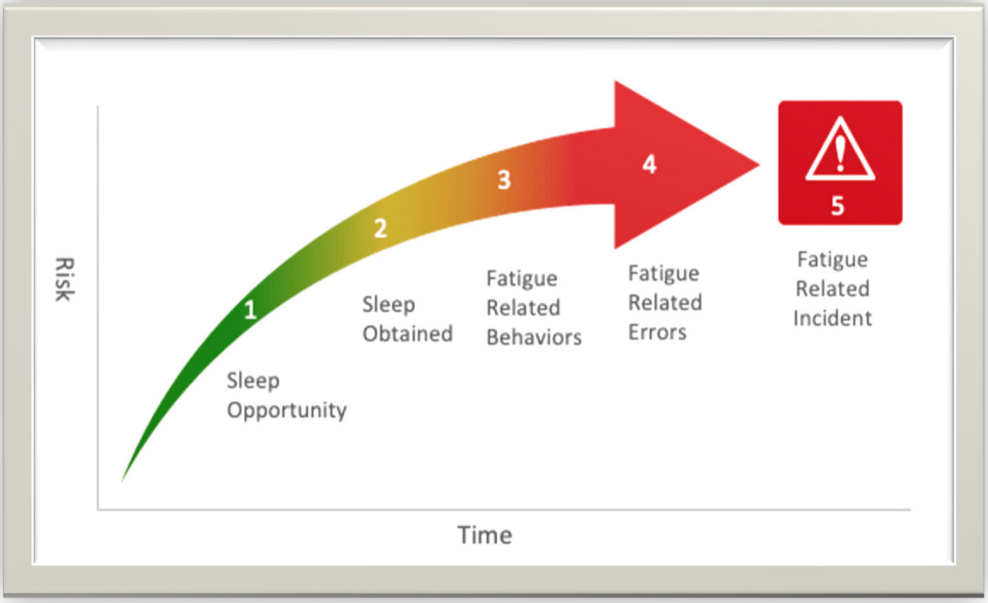
- Lighting and ventilation appropriate to the working environment and promote wakefulness
- Noise and heat levels appropriate to the working environment and promote wakefulness
- Provision of appropriate first aid facilities
- Access to drinking water
- Availability of areas and/or facilities to make and store fresh meals
- Design tasks so that individuals can concentrate on core activities but also maintain a stimulus to minimize boredom and vary physical workload.

Behavior During Non-Work Hours and Readiness for Duty

Individuals have a responsibility to ensure they present themselves in a fit and rested state when returning from time off.

- Two days before returning to work from a break longer than four days, consideration should be given to any variation in sleep patterns or lifestyle that may impact an individual's ability to carry out their work without risk. Individuals should align their behaviors and sleep patterns as closely as possible to their work routine to manage their fatigue.
- When there is a need to return to work on a night shift, the individual should limit physical activity and have at least 4 hours of sleep/naps throughout the day before the shift.

7. FATIGUE HAZARD ASSESSMENT and FATIGUE MANAGEMENT PLAN



Organizations should develop and implement a Fatigue Hazard Assessment (FHA) and a Fatigue Management Plan (FMP) to comprehensively identify potential hazards associated with work activities and manage these risks properly. Hazards may be ranked based on risk (e.g., probability multiplied by severity) and detailed in the Risk Matrix.

Fatigue Risk Matrix

Record and quantify risk level of fatigue hazards on site/project.

- Defines value for intersection of Severity and Likelihood of impacts from a fatigue hazard
- Intersect value corresponds to an action table defining options on a path forward based on the score (ex. – ok as is / monitor only, mitigate, or stop)

Fatigue Management Plan Implementation

- If an FMP is warranted and developed for a project, this should be communicated to all project workers.
- All affected employees will be trained on the FMP. The training should include, at a minimum:
  - The hazards identified and addressed in the plan
  - The mitigation strategies for the hazards identified
  - Their role in the implementation of the plan
- The affected workforce should be consulted regarding the FHA and the FMP when establishing working hour arrangements and setting up programs to minimize fatigue.
- All work should be assessed to determine potentials for fatigue risk in personnel in the pre-mobilization and mobilization phases by the project team to reduce the potential for injury and property damage.

The FHA and the FMP enable the project team to determine the risks and their approach to managing fatigue in a manner best suited for workers, operational needs, and the workplace environment. The FMP shall take into consideration the following:

Sleep Loss

- Overtime
- Long work hours / weeks (unpredictability)
- Commute and travel (remote location, distance to location, etc.)
- Personal factors ('fit for duty' / health conditions, mental health / stress, living conditions, etc.)

Circadian Challenges

- Windows of low circadian rhythm
- Diet
- Shift Work
- Workplace environment

Task Factors

- Scheduling (shift planning, timing of critical tasks, resources, adequacy of crew, need for night shifts, etc.)
- Staffing levels, staging of work, and programming of rosters as required to safely complete work in accordance with production schedules
- Any potential for call-outs or extended work hours
- Project duration (how long in this condition, how far away from home, etc.)
- Work place environmental factors (weather – hot/cold – heat and cold stress, humidity, lighting – sufficient at darker hours, time of day and any need for acclimatization)
- Task design including complexity, demand level, physical and mental requirements, ergonomic considerations, PPE requirements and impacts (e.g. respiratory protection, Tyvek suits), mundane tasks, etc.
- Repetitive nature of work and potential for associated fatigue or stress issues
- Mental demands (budget, schedule, management, timr away from home, etc.)
- Work tempo (break frequencies, lack of relief / breaks)

General Hazards

- Schedule (impacts to multiple workers – long hours, limited time to complete, urgent approach, fast tempo, etc.)
- Commuting and travel (fatigued driving, night travel, distance to site, distance from home, etc.)
- Worker readiness (at kickoff, return from time off, prior to time off)
- Worker-specific personal factors that may impact fatigue, such as worker health, age, or any known medical issues (consider any history or records of fatigue reports and fatigue-related incidents or illness relating to an individual project or group of workers)
- Team cohesiveness (team morale, brother/sister's keeper, etc.)
- Resource constraints (people, equipment, sufficient room to work, time allowed to work safely, etc.)
- Suitability of company-provided worker accommodation and food
- Availability of leisure and recreational facilities for workers

- Lack of support from management
- Individual or team priority to continue task against fatigue best management practices (BMPs)

THE USE OF TECHNOLOGY TO MANAGE FATIGUE RISK

An FRMS is a data-driven multi-layered system of defense to combat the negative effects of worker fatigue, principally fatigue related incidents (FRI).[49] Among these layers, the first one consists of (a) preventing the development of fatigue among workers by providing adequate schedules, workload, and opportunities to recover from their activities. The second layer of defense consists of (b) identifying when a worker is fatigued. The third layer requires (c) quantifying the risk associated with specific fatigue levels. Then, an FRMS should (d) outline procedures to mitigate fatigue-related risks when certain thresholds are reached. Lastly, an FRMS should (e) put measures in place to protect employees and the public from FRI, even if a worker operates under the effects of fatigue. Technology offers tools to enhance parallel efforts conducted by other FRMS protocols to maintain each of these layers of defense in place.[50]

Although necessary, hours of service (HOS) limitations have shown to be insufficient to manage fatigue-related risks properly. Using technology as part of an FRMS could offer more flexible schedules while keeping workers safe. Nonetheless, this approach needs to be thoroughly studied and carefully implemented by each company.

As previously defined in this document, some level of fatigue is experienced by most people daily, and perhaps for this reason, it is difficult to pinpoint its appearance in our body and, even more so, to quantify its impact. Nonetheless, fatigue manifests through several physiological changes, which technology can objectively identify.

Fatigue Prevention

A fatigue-preventing culture and a culture of collaboration, support, and trust are indispensable to reducing FRI. Technology plays a supportive role in educating all parties and the maturation of the organization's safety culture. Furthermore, current technology can also play a direct and active role in the prevention of fatigue by offering employers the ability to organize schedules to minimize their impact on the worker's circadian rhythm through Biomathematical Models, thus improving alertness and productivity among workers. Software based on biomathematical modeling can assist with scheduling to minimize fatigue and maximize performance effectiveness, cognitive performance, reaction times, attention spans, etc.[50,51]

While scheduling work on the right-of-way or inside of a plant will not bear as many variables as the software is capable of factoring, the value of the software could be integral to the planning process. The scheduling tools will enable Project Managers to compare minor variations in schedules that could have monumental differences in the performance of the labor force. Likewise, changes in scheduling for construction deadlines can be evaluated for the cognitive impact on the workforce.

Scheduling technology that utilizes biomathematical modeling is not intended to be a stand-alone fatigue management tool. This technology is designed to be part of a robust Fatigue Management Program, and the value and reliability of the output depend on the inputs' quality. A limitation of this technology is that the models predict the potential for fatigue risk for average individuals working a predetermined schedule, and it relies on the user to input thresholds for acceptable risk.[52]

Technology to Identify and Quantify Fatigue

The technological advances of the last few decades have given place to numerous devices that claim to quantify fatigue by measuring one or more physiological change, see Figure 2, or behavioral change, see Figure 3, induced by fatigue (i.e., eyelid movement, reaction time, brain wave activity, hand-eye coordination, gait, etc.), by tracking fatigue-related risks such as extensive periods of wakefulness, or changes in performance through equipment embedded devices. These technologies were built to determine when a person is reaching a high level of fatigue associated with a high safety risk. Most of these technologies are still in their developmental phase and require further validation. Nonetheless, the future is promising for fatigue risk quantification.[53]

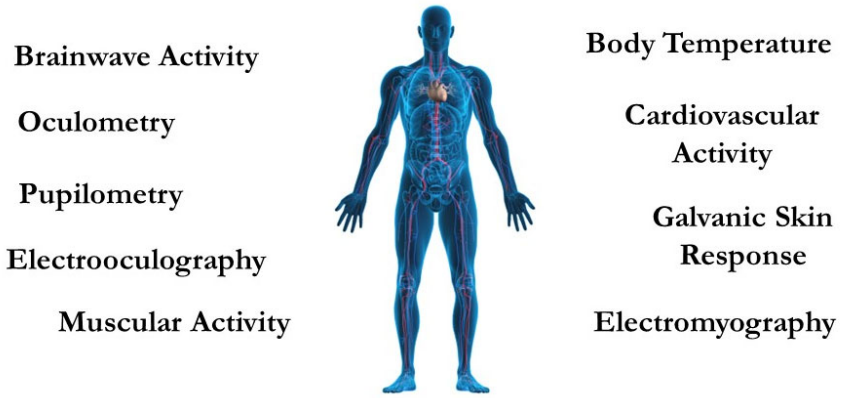


Figure 2: Techniques to Assess Fatigue Through Physiological Variables

Figure 3: Behavioral Variables to Assess Fatigue

Technology for Fatigue Related Incident Mitigation

Technology, for the most part, plays an advisory role in mitigating FRI. When a specific level of fatigue is associated with a high level of risk, it can alert the worker, a supervisor, and a central location about the dangerous situation. At that point, workers can react and protect themselves, see Figure 4. Their reaction will largely depend on their safety culture, trust in the technology, and the perceived support from their supervisor or company. If the worker has a strong safety culture, the technology is reliable, and they are

sure that their employer will not retaliate for their action, then it is likely that the worker will make the safest decision.[50]

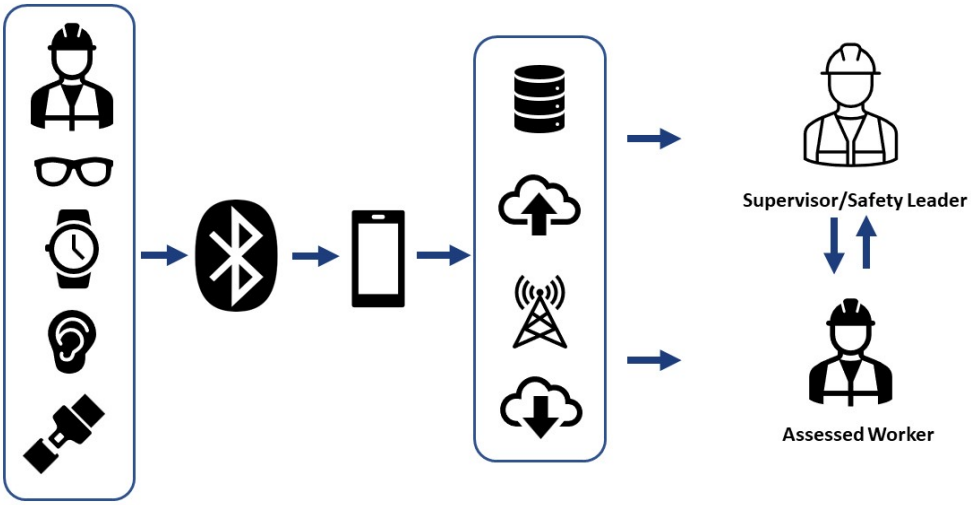


Figure 4: Fatigue Risk Technology Alert Path

Technology for Fatigue Proofing

Certain risks can be mitigated or eliminated by implementing automatic safety actions when it is detected that the operator is experiencing high levels of fatigue. For instance, a worker may be using a dangerous piece of equipment, which will stop working if the technology determines that the worker is fatigued, much like an engineering control, see Figure 5. This approach is perhaps the safest. However, it may not be practical or possible in some situations.[54]

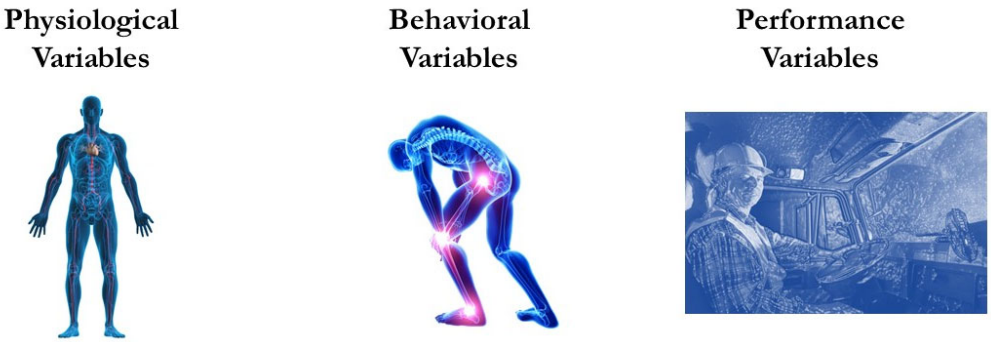


Figure 5: Fatigue Assessment Variables

Continuous Improvement

Data collection allows for the continuous improvement of an FRMS by identifying trends in the data that could correlate to specific root causes, which may go unidentified otherwise.[55] Furthermore, technology can determine a baseline in the early implementation of an FRMS, set goals, and then evaluate the system's efficacy in achieving those goals. Some examples of these goals may include a reduction in a

company's healthcare costs or an improvement in workers' performance in a fitness for duty test, among others.[51] It is also essential to keep in mind that some of these indicators depend on several variables besides worker fatigue. Therefore, caution must be applied in decision-making when using this data.

How to Implement Fatigue Management Technology

Technology can be a strong ally in the management of fatigue to prevent incidents. Company safety leaders must thoroughly evaluate any technology or product to confirm that it has been validated to be effective as applied within the workplace before it is deployed. The use of fatigue management experts from the academic and consulting sector is fundamental when considering the implementation of technology as part of an FRMS to achieve higher safety goals.[56]

Implement a hybrid approach

One way to minimize the risk of over-relying on a specific technology and to increase the robustness of a fatigue monitoring system is to implement a hybrid approach in which several technologies are used in unison, see Figure 6. This multi-technological approach to fatigue management allows safety managers to see congruences among different technologies, thus adding confidence to the overall assessment of workers' situation and diminishing the risk of failures in the system. If one of these technologies were to fail in the assessment of fatigue levels and associated risk, another technology could still make the proper assessment.[50,57]

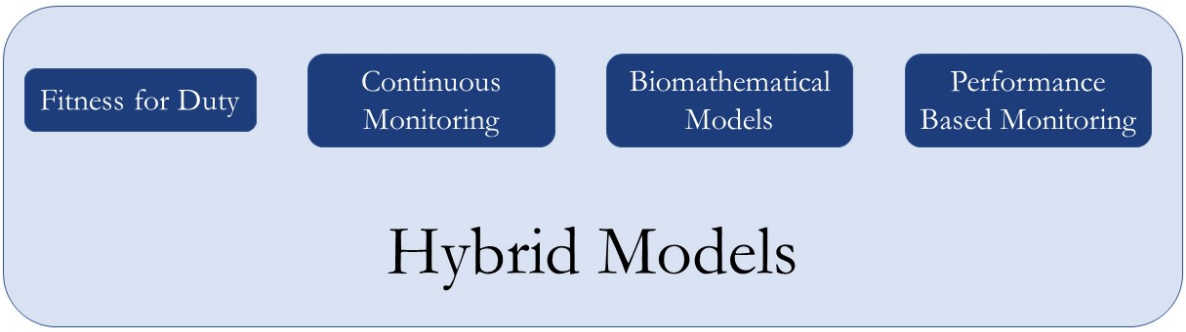


Figure 6: Hybrid Models Technologies

Optimizing resources allocation

Implementing technology requires capital, and ways to maximize the return on investment should be considered. In this planning phase, fatigue management experts and company safety leaders should consider the workers and activities that are at a higher risk of experiencing an FRI and derive resources for those workers primarily (risk-based implementation).[51] Additionally, these professionals should consider what technologies best fit each type of work. Risk-based implementation will optimize resource allocation by investing more in those workers at a higher risk of experiencing an FRI and less in those who present a lower risk, either because they are less exposed to fatigue or because if an FRI occurs, the risk associated to it is lower.[54]

Empowering the workforce and strengthening the company

The principal objective of implementing fatigue monitoring and detection technologies is to keep workers safe, which is usually accompanied by higher worker satisfaction and improved levels of worker retention

and productivity. To achieve this, it is essential to develop a culture of trust and empower the worker through education and active communication. Open and frequent communication to convey the technology's purpose, the gathered data's characteristics, and a thorough explanation of how the data will be used is essential for the successful implementation of any technology. The implementation of technology presents an opportunity to build a culture of trust and reap its fruits. If workers understand that these technologies can save their lives and believe that taking advantage of them is in their best interest, they will comply with their use and respect their warnings. Conversely, if a culture of punishment is developed instead, workers will circumvent the technology and ignore the warnings. Consequently, how technology is implemented may be more important than the characteristics of the technology itself.[58–60]

One of the common fears of technology implementation has to do with the characteristics of the data collected and its management. Employees worry about data privacy, and employers worry about liability. When technology is introduced following the guide of subject matter experts and the data handling is outsourced to a third-party entity, these concerns can be minimized. When applicable, these third-party entities can guarantee compliance with the Health Insurance Portability and Accountability Act (HIPAA). A subject matter expert will ensure the implementation of reliable technology and the correct interpretation of its output, thus minimizing the liability associated with decision-making based on these outputs. Additionally, unless there is a reoccurring issue related to work operations or that has a potential impact on other workers, an employer doesn't need to know why a worker is experiencing high levels of fatigue. Instead, the employer needs to know when it is happening and how they can help. To make this possible, it is recommended to leave the data management to a third-party organization with qualified personnel to correctly analyze the data and send alerts to the workers and employers when necessary. This third party can also provide real-time data to employers and employees, taking full advantage of the technology while respecting worker's privacy. This approach provides an additional level of protection to employers by leaving the data interpretation to that third party while giving the employer the opportunity to support its employees when needed.[50]

A common fear among employers and employees, when considering fatigue management, is the reduction in work hours. Employers need to fulfill a growing number of work orders with a limited workforce. The bottom line is that worker safety takes precedence over earning money and productivity, as no monetary compensation can compensate for the loss of a life and its consequences to families and employers. Technology offers an avenue to manage these different interests by monitoring worker risk while at work, thus improving worker safety.[58,60]

To sum up, when correctly implemented, under the guidance of a subject matter expert, with the full support of company management, and as a sub-part of an FRMS, technology can significantly aid in achieving a company's goals by improving safety and productivity. Furthermore, the data provided by this technology will allow for a continuous assessment and improvement of any FRMS, thus guaranteeing continuous improvement.

8. HAZARD MITIGATION / FATIGUE EXPOSURE CONTROLS

Pre-Task / Pre-Job Planning

Prior to commencing and executing the work in the field, the Pre-Task Risk Assessment (PTRA), Field Level Hazard / Risk Assessment (FLHA / FLRA) or equivalent process should include a review of fatigue mitigation controls relevant to the upcoming scope of work.

Job Safety Analysis (JSA)

- The JSA should include a review of fatigue symptoms. Workers should be encouraged to watch themselves and others for fatigue symptoms.
- The JSA should review break policies, hydration, and food intake during the work shift to mitigate the onset of fatigue.
- During the JSA, workers should receive instructions on how to proceed if they identify a fatigue risk, and they should be reminded of their authority to stop work if necessary.

Incident/Near Miss Investigation

- Include fatigue consideration as a factor at the onset of any incident/near miss investigation
- Perform fatigue risk assessment post incident to rank fatigue factors at time of incident

Deviation Process

- Clear requirements should be followed to establish when a variance is an acceptable path to pursue

- Define any controls that must be used for variance approval
- Define conditions that do not qualify for variance approval

Risk Mitigation

Proactive steps should be taken to mitigate fatigue impacts on employees. Below are some strategies which can benefit the project:

- Periodically analyze and evaluate work tasks to control fatigue.
- Address all areas that prompt mitigation based on scoring from the Risk Assessment Tool.
- Provide adequate staffing levels to avoid regularly working excessive hours.
- Design schedules to minimize the potential for fatigue related problems.
- Consideration of personal factors when selecting people for work.
- Monitor relevant factors, and encourage managers, supervisors, and staff to be aware of potential problems.
- Ensure all personnel receive adequate rest periods between shifts.
- Allow regular short breaks during shifts.
- Assess the availability and use of ergonomic-friendly equipment.
- Provide employees with information on the need for sufficient sleep and proper nutrition.
- Provide training on the importance of good eating habits including avoidance of energy drinks and other stimulants.

Monitoring

The Site Manager shall ensure that systems are in place to monitor fatigue levels. Monitoring can consist of, but is not limited, to:

- Encouraging self-reporting
- Being mindful of signs/symptoms for self and others
- Maintaining fatigue management as a key JSA/tailgate topic
- Worker supervision
- Monitoring and approval of overtime hours
- Perform routine fatigue risk assessments to ensure alignment with FMP/FRMS
- Incident analysis with specific reference to time of day, percentage of shift worked, and any additional fatigue-related factors

Continuous Improvement

- An FRMS is a living system which should collect data on a regular basis to evaluate its progress and define improvement strategies. Technology and data analysis should give place to policy adjustments and the implementation of new strategies to continuously improve the FRMS.
- Understanding and learning from events where fatigue was a factor allows individuals and the collective workforce to evolve and better manage fatigue in the workplace. Some best practices include:
    - Capture and share fatigue-related events
    - Incorporate learnings into future project planning and task design

Fatigue Impairment Assessment

Where personnel are working long hours or longer than normal shifts, they should be observed for signs of fatigue. An evaluation of the risk involved in the individual continuing to perform their work duties should be carried out between the individual and their supervisor. An example of a fatigue Risk Assessment Tool is attached as a guideline.

Risk Assessment (Tool) usage:

- Include all identified fatigue hazards (sleep loss, circadian challenges, task factors, general hazards, etc.)
- Assign weighting / value to hazards and assemble in a manner to allow for quantification of the total fatigue risk
- Apply the risk matrix score to each hazard and total the count for each
- Define the path forward based on score and corresponding action from the risk matrix
- Share all findings with those being assessed
- If the risk is judged to be unacceptable, appropriate actions to manage and minimize the risk must be identified.

9. TRAINING

Initial and annual training should be provided on how to recognize fatigue, how to control fatigue through appropriate work and personal habits and reporting of fatigue to supervisors.

New Employee Orientation

The following topics should be discussed in the new employee orientation:

- The employee's roles and responsibilities in the FRMS
- Hazards associated with fatigue
- Components of this policy and its guidelines
- Proper fatigue management practices
    - Utilizing time off to get restorative sleep
    - The importance of good eating habits
    - Avoidance of energy drinks and prescription or over-the-counter stimulants
- Reporting protocols
- Use of Stop Work Authority
- Roles and Responsibilities
- Use of the Fatigue Risk Assessment Tool

Employee Training Requirements

Refresher training should be provided annually and/or whenever a change in the policy is made.

10. HISTORY OF REVISIONS

Revision	Date	Description
0	2/7/2024	Initial Issue

REFERENCES

1. INGAA. Who We Are. INGAA. Published 2023. Accessed September 29, 2023. https://ingaa.org/about-ingaa/
2. Chan M. Fatigue: The most critical accident risk in oil and gas construction. *Construction Management and Economics*. 2011;29(4):341-353.
3. Techera U, Hallowell M, Stambaugh N, Littlejohn R. Causes and Consequences of Occupational Fatigue: Meta-Analysis and Systems Model. *Journal of Occupational and Environmental Medicine*. 2016;58(10):961-973. doi:10.1097/JOM.0000000000000837
4. Techera U, Hallowell M, Littlejohn R. Worker Fatigue in Electrical-Transmission and Distribution-Line Construction. *Journal of Construction Engineering and Management*. 2019;145(1):04018119. doi:10.1061/(ASCE)CO.1943-7862.0001580
5. Harrison Y, Horne JA. One night of sleep loss impairs innovative thinking and flexible decision making. *Organ Behav Hum Decis Process*. 1999;78(2):128-145. doi:10.1006/obhd.1999.2827
6. Harrison Y, Horne JA. The impact of sleep deprivation on decision making: a review. *J Exp Psychol Appl*. 2000;6(3):236-249. doi:10.1037//1076-898x.6.3.236
7. Brown ID. Driver Fatigue. *Hum Factors*. 1994;36(2):298-314. doi:10.1177/001872089403600210
8. Fogt DL, Kalns JE, Michael DJ. A Comparison of Cognitive Performance Decreases During Acute, Progressive Fatigue Arising From Different Concurrent Stressors. *Military Medicine*. 2010;175(12):939-944. doi:10.7205/MILMED-D-10-00093
9. YOSHITAKE H. Three Characteristic Patterns of Subjective Fatigue Symptoms. *Ergonomics*. 1978;21(3):231-233. doi:10.1080/00140137808931718
10. Angus RG, Heslegrave RJ. Effects of sleep loss on sustained cognitive performance during a command and control simulation. *Behavior Research Methods, Instruments, & Computers*. 1985;17(1):55-67. doi:10.3758/BF03200897
11. Naitoh P. Circadian cycles and restorative power of naps. *Biological rhythms, sleep and shift work*. Published online 1981.
12. Opstad PK, Ekanger R, Nummestad M, Raabe N. Performance, mood, and clinical symptoms in men exposed to prolonged, severe physical work and sleep deprivation. *Aviat Space Environ Med*. 1978;49(9):1065-1073.
13. Johnston RB, Howard ME, Cawley PW, Losse GM. Effect of lower extremity muscular fatigue on motor control performance. *Med Sci Sports Exerc*. 1998;30(12):1703-1707. doi:10.1097/00005768-199812000-00008
14. Grandjean E. Fatigue in industry. *Occupational and Environmental Medicine*. 1979;36(3):175-186. doi:10.1136/oem.36.3.175
15. Tixier AJP, Hallowell MR, Albert A, van Boven L, Kleiner BM. Psychological Antecedents of Risk-Taking Behavior in Construction. *Journal of Construction Engineering and Management*. 2014;140(11):04014052. doi:10.1061/(ASCE)CO.1943-7862.0000894
16. Boonstra TW, Stins JF, Daffertshofer A, Beek PJ. Effects of sleep deprivation on neural functioning: an integrative review. *Cell Mol Life Sci*. 2007;64(7):934. doi:10.1007/s00018-007-6457-8

17. Dinges DF, Pack F, Williams K, et al. Cumulative Sleepiness, Mood Disturbance, and Psychomotor Vigilance Performance Decrements During a Week of Sleep Restricted to 4–5 Hours per Night. *Sleep*. 1997;20(4):267-277. doi:10.1093/sleep/20.4.267
18. Kajtna T, Štukovnik V, Grošelj LD. UEffect of acute sleep deprivation on concentration and mood states with a controlled effect of experienced stress. *Slovenian Medical Journal*. 2011;80(5). Accessed October 22, 2022. https://vestnik.szd.si/index.php/ZdravVest/article/view/163
19. McNair DM, Lorr M, Droppleman LF. Profile of mood states, revised (POMS). *San Diego, CA: EdITS/Educational and Industrial Testing Service*. Published online 1981.
20. Pilcher JJ, Huffcutt AI. Effects of Sleep Deprivation on Performance: A Meta-Analysis. *Sleep*. 1996;19(4):318-326. doi:10.1093/sleep/19.4.318
21. Sagaspe P, Sanchez-Ortuno M, Charles A, et al. Effects of sleep deprivation on Color-Word, Emotional, and Specific Stroop interference and on self-reported anxiety. *Brain and Cognition*. 2006;60(1):76-87. doi:10.1016/j.bandc.2005.10.001
22. Scott JPR, McNaughton LR, Polman RCJ. Effects of sleep deprivation and exercise on cognitive, motor performance and mood. *Physiology & Behavior*. 2006;87(2):396-408. doi:10.1016/j.physbeh.2005.11.009
23. Craig A, Cooper RE. 11 - Symptoms of Acute and Chronic Fatigue. In: Smith AP, Jones DM, eds. *State and Trait*. Academic Press; 1992:289-339. doi:10.1016/B978-0-12-650353-1.50017-4
24. Czeisler CA, Dumont M, Duffy JF, et al. Association of sleep-wake habits in older people with changes in output of circadian pacemaker. *Lancet*. 1992;340(8825):933-936. doi:10.1016/0140-6736(92)92817-y
25. van der Linden D, Frese M, Meijman TF. Mental fatigue and the control of cognitive processes: effects on perseveration and planning. *Acta Psychol (Amst)*. 2003;113(1):45-65. doi:10.1016/s0001-6918(02)00150-6
26. Lorist MM, Klein M, Nieuwenhuis S, Jong RD, Mulder G, Meijman TF. Mental fatigue and task control: Planning and preparation. *Psychophysiology*. 2000;37(5):614-625. doi:10.1111/1469-8986.3750614
27. Knutsson A. Health disorders of shift workers. *Occupational Medicine*. 2003;53(2):103-108. doi:10.1093/occmed/kqg048
28. Segawa K, Nakazawa S, Tsukamoto Y, et al. Peptic ulcer is prevalent among shift workers. *Digestive diseases and sciences*. 1987;32(5):449-453.
29. Bøggild H, Knutsson A. Shift work, risk factors and cardiovascular disease. *Scandinavian Journal of Work, Environment & Health*. 1999;25(2):85-99.
30. Steenland K, Fine L. Shift work, shift change, and risk of death from heart disease at work. *American Journal of Industrial Medicine*. 1996;29(3):278-281. doi:10.1002/(SICI)1097-0274(199603)29:3<278::AID-AJIM8>3.0.CO;2-M
31. Iwasaki K, Sasaki T, Oka T, Hisanaga N. Effect of Working Hours on Biological Functions related to Cardiovascular System among Salesmen in a Machinery Manufacturing Company. *Industrial health*. 1998;36(4):361-367. doi:10.2486/indhealth.36.361
32. Lim J, Dinges DF. A meta-analysis of the impact of short-term sleep deprivation on cognitive variables. *Psychological Bulletin*. 2010;136(3):375-389. doi:10.1037/a0018883

33. Van Dongen HPA, Dinges DF. Sleep, circadian rhythms, and psychomotor vigilance. *Clin Sports Med*. 2005;24(2):237-249, vii-viii. doi:10.1016/j.csm.2004.12.007
34. Czeisler CA, Duffy JF, Shanahan TL, et al. Stability, Precision, and Near-24-Hour Period of the Human Circadian Pacemaker. *Science*. 1999;284(5423):2177-2181. doi:10.1126/science.284.5423.2177
35. Bjorvatn B, Pallesen S. A practical approach to circadian rhythm sleep disorders. *Sleep Medicine Reviews*. 2009;13(1):47-60. doi:10.1016/j.smrv.2008.04.009
36. Boivin DB, Boudreau P. Impacts of shift work on sleep and circadian rhythms. *Pathologie Biologie*. 2014;62(5):292-301. doi:10.1016/j.patbio.2014.08.001
37. Folkard S. Do Permanent Night Workers Show Circadian Adjustment? A Review Based on the Endogenous Melatonin Rhythm. *Chronobiology International*. 2008;25(2-3):215-224. doi:10.1080/07420520802106835
38. Dijk DJ, Czeisler CA. Contribution of the circadian pacemaker and the sleep homeostat to sleep propensity, sleep structure, electroencephalographic slow waves, and sleep spindle activity in humans. *J Neurosci*. 1995;15(5):3526-3538. doi:10.1523/JNEUROSCI.15-05-03526.1995
39. Dijk DJ, Brunner DP, Beersma DGM, Borbély AA. Electroencephalogram Power Density and Slow Wave Sleep as a Function of Prior Waking and Circadian Phase. *Sleep*. 1990;13(5):430-440. doi:10.1093/sleep/13.5.430
40. Åkerstedt T. Psychological and psychophysiological effects of shift work. *Scandinavian Journal of Work, Environment & Health*. 1990;16:67-73.
41. Boivin DB, Tremblay GM, James FO. Working on atypical schedules. *Sleep Medicine*. 2007;8(6):578-589. doi:10.1016/j.sleep.2007.03.015
42. Schwartz JRL, Roth T. Shift Work Sleep Disorder. *Drugs*. 2006;66(18):2357-2370. doi:10.2165/00003495-200666180-00007
43. NIH. Sleep Apnea - What Is Sleep Apnea? | NHLBI, NIH. Nathional Health, Lung, and Blood Institute. Published March 24, 2022. Accessed September 20, 2023. https://www.nhlbi.nih.gov/health/sleep-apnea
44. Mayo Clinic S. Sleep apnea - Symptoms and causes. Mayo Clinic. Published April 3, 2023. Accessed September 20, 2023. https://www.mayoclinic.org/diseases-conditions/sleep-apnea/symptoms-causes/syc-20377631
45. Mayo Clinic S. Insomnia - Symptoms and causes. Mayo Clinic. Published October 15, 2016. Accessed September 20, 2023. https://www.mayoclinic.org/diseases-conditions/insomnia/symptoms-causes/syc-20355167
46. Suni E, Rehman A. Insomnia: Symptoms, Causes, and Treatments. Sleep Foundation. Published October 13, 2018. Accessed September 20, 2023. https://www.sleepfoundation.org/insomnia
47. Mayo Clinic S. Narcolepsy - Symptoms and causes. Mayo Clinic. Published January 14, 2023. Accessed September 20, 2023. https://www.mayoclinic.org/diseases-conditions/narcolepsy/symptoms-causes/syc-20375497
48. Axe J. nutrition breakthroughs sleep minerals Archives. Nutrition Breakthroughs. Published June 15, 2018. Accessed September 21, 2023. https://www.nutritionbreakthroughs.com/tag/nutrition-breakthroughs-sleep-minerals/

49. Sprajcer M, Thomas MJW, Sargent C, et al. How effective are Fatigue Risk Management Systems (FRMS)? A review. *Accident Analysis & Prevention*. 2022;165:106398. doi:10.1016/j.aap.2021.106398
50. Dawson D, McCulloch K. Managing fatigue: It's about sleep. *Sleep Medicine Reviews*. 2005;9(5):365-380. doi:10.1016/j.smrv.2005.03.002
51. Dawson D, Searle AK, Paterson JL. Look before you (s)leep: Evaluating the use of fatigue detection technologies within a fatigue risk management system for the road transport industry. *Sleep Medicine Reviews*. 2014;18(2):141-152. doi:10.1016/j.smrv.2013.03.003
52. McCauley ME, McCauley P, Riedy SM, et al. Fatigue risk management based on self-reported fatigue: Expanding a biomathematical model of fatigue-related performance deficits to also predict subjective sleepiness. *Transportation Research Part F: Traffic Psychology and Behaviour*. 2021;79:94-106. doi:10.1016/j.trf.2021.04.006
53. Techera U, Hallowell M, Littlejohn R, Rajendran S. Measuring and Predicting Fatigue in Construction: Empirical Field Study. *Journal of Construction Engineering and Management*. 2018;144(8):04018062. doi:10.1061/(ASCE)CO.1943-7862.0001513
54. Dawson D, Chapman J, Thomas MJW. Fatigue-proofing: A new approach to reducing fatigue-related risk using the principles of error management. *Sleep Medicine Reviews*. 2012;16(2):167-175. doi:10.1016/j.smrv.2011.05.004
55. Horrey WJ, Noy YI, Folkard S, Popkin SM, Howarth HD, Courtney TK. Research needs and opportunities for reducing the adverse safety consequences of fatigue. *Accident Analysis & Prevention*. 2011;43(2):591-594. doi:10.1016/j.aap.2010.01.014
56. Dawson D. Validation in the context of commercialization : the white rabbit effect. Published online January 1, 2011. doi:10.1016/j.sleep.2011.01.004']
57. Gander P, Hartley L, Powell D, et al. Fatigue risk management: Organizational factors at the regulatory and industry/company level. *Accident Analysis & Prevention*. 2011;43(2):573-590. doi:10.1016/j.aap.2009.11.007
58. Hartley L, Horberry T, Mabbott N, Krueger GP. *Review of Fatigue Detection and Prediction Technologies*. Melbourne: National Road Transport Commission; 2000.
59. Hartley L, Horberry T, Mabbott N. REVIEW OF FATIGUE DETECTION AND PREDICTION TECHNOLOGIES. Published online August 23, 2021.
60. Wright NA, Stone BM, Horberry TJ, Reed N. A Review of In-Vehicle Sleepiness Detection Devices. *TRL Published Project Report*. Published online 2007. Accessed May 18, 2021. https://trid.trb.org/view/809063

APPENDIX A: EMPLOYEE FATIGUE MANAGEMENT PLAN

Employee Name: .....

Supervisor Name: .....

Crew: .....

1. Specific Concerns:

.....

2. Employee's lifestyle impacts contributing to fatigue:

.....

3. Employee's current fatigue management strategies:

.....

4. Other agreed fatigue management strategies *(between Employee & Supervisor)*:

.....

5. Incidents of feeling fatigued or falling asleep whilst at work:

.....

ACTION PLAN:

1. .....

   .....

2. .....

   .....

3. .....

   .....

4. .....

APPENDIX B: FATIGUE MANAGEMENT INFORMATION

1. Principal Cause of Fatigue

- The principal cause of work-related fatigue in shift workers is the disruption to the body clock, circadian rhythms, by sleeping at times when the body is not used to sleeping. This body clock never completely adjusts, even in people who work the night shift permanently.
- Shifts that carry into the night or begin very early in the day, and schedules that require many consecutive days of extended working hours, may create a similar problem.
- Pipeline projects do not generally involve shift work but may require extended working hours over a number of days.

2. Hours of Sleep

- Sleep deprivation, which may lead to what is called "sleep debt", refers to inadequate or poor sleep over a period of days. Sleep debt is essentially the accumulation of lost hours of sleep over a number of days or weeks.
- Not all times of day are equally conducive to sleep.
- There are zones for sleep between 8am and 12 noon and 5pm and 9pm during which it can be more difficult to get to sleep.
- Daytime sleep is lighter and shorter and less recuperative than night sleep.
- 12 hours break starting at 7am will generally produce less quality sleep than a 12-hour break at 7pm

Symptoms of Fatigue

Symptoms vary between people. Below are some of the potential health effects of fatigue.

1. Physical Symptoms

- Constant yawning
- Making fewer and larger steering corrections when driving
- Feeling irritable and impatient
- Poor concentration
- Drowsiness
- Involuntary micro-sleeps
- Letting the vehicle wander across lanes
- Tired or sore eyes
- Slow reactions
- Poor hand eye coordination
- Missing road signs
- Restlessness
- Blurred or double vision Driving at different speeds

2. Psychological Symptoms

- At the most fundamental level, fatigue results in cognitive 'disengagement' or 'withdrawal' from the operating environment.
- Fatigued workers have difficulty coping when:
  - Appreciating a complex situation while avoiding distraction

- Keeping track of the current situation and updating strategies
- Thinking laterally and being innovative
- Assessing risk and/or anticipating consequences
- Maintaining interest in outcome
- Controlling mood and avoiding inappropriate behavior

3. Factors Influencing Sleep

- There are several factors that influence the amount of sleep an individual receives. This disturbance occurs either by reducing the time available/allocated for sleep or reducing the quality/quantity of the sleep (see Figure 1).
- Research indicates that an average person needs a minimum of 6 hours of "quality" uninterrupted sleep per 24 hours period.
- Work schedules should allow for sufficient time to meet the minimum required 6 hours of sleep.
- Biological constraints of the body: humans are biologically hardwired to sleep during the night, (sleep during the day will be of an inferior quality to sleep during the night)
- Rotation of shifts ("clockwise" is better than "anti-clockwise")
- The number of consecutive shifts worked before a break (incident risk increases with number of consecutive shifts worked)
- Timing and length of shifts (limiting shifts to 12 hours, ending no later than 8am)
- Timing and length of breaks (employees should self-select and have minimum number of breaks)
- Work/wake history during the preceding 7 days (sleep debt)
- Time required to commute to and from work (it affects the amount of time available for sleep and must be considered when developing rosters)
- Greater workload within shifts (complex tasks should be scheduled during the day, and more routine/active tasks at night)
- Extended periods of boring or repetitive tasks (concentration decreases)
- Situations requiring focused concentration for extended periods during work hours, working in extremes of temperature, vibration or noise and working for extended periods with high-risk situations

Figure 1: Factors Which Influence an Individual's Sleep
[Adapted from: Work Design, Fatigue and Sleep (Minerals Council, 2004)]

4. **Non-Work-Related Issues Impacting Fatigue**
    - Causes of non-work-related fatigue include:
        - Sleep disruption due to family illness
        - Stress associated with financial or domestic issues
        - Personal lifestyle choices

5. **Fatigue and Performance**
    - Fatigue impairs performance across several functions – these are principally:
        - Decrease in task performance
        - Decrease in reaction time
        - Increased probability of falling asleep
        - Subjective feelings of drowsiness
        - Cognitive impairment i.e. The ability to process information and make timely and appropriate decisions or actions decreases
        - An increase in risk taking behavior.
        - Mood changes and decrease in motivation

- The effects of fatigue are not dissimilar to those produced by alcohol impairment.
- Studies show that 17 hours without sleep may have the same effect on task performance as a Blood Alcohol Content (BAC) of 0.05%.
- At 24 hours it is equivalent to a BAC of 0.10%.

6. Health Impacts of Long-Term Fatigue

- Long-term exposure to fatigue has been indicated to cause health problems such as:
  - Digestive problems
  - Bowel habit alteration
  - Increased risk of heart disease
  - Increased risk of peptic ulcers
  - Stress or mental illness.
- The detrimental effects of long-term fatigue can be exacerbated by:
  - Diabetes
  - Epilepsy
  - Asthma
  - Depression

APPENDIX C: FATIGUE RISK ASSESSMENT TOOL

Please, see spreadsheet file attached