STANDARDS RESEARCH

Workplace Fatigue: Current Landscape and Future Considerations

October 2019

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Executive Summary

Introduction

People are experiencing unprecedented levels of workplace fatigue due to a combination of modern day work, societal, and personal pressures that may include high physical or mental workloads, long work hours, circadian disruptions from work schedules and inadequate restorative sleep by individuals [1-4]. The purpose of this report is to synthesize evidence from the literature and an environmental scan to define workplace fatigue and identify existing national and international legislation and best practices related to workplace fatigue. Promising practices for Canadian workplaces were also identified, and a gap analysis was performed detailing the need for a national standard or other standards-based solutions (e.g., training, assessment tools, guidelines, etc.) on fatigue risk management.

Methods

A literature review and environmental scan were conducted using online and library-based searches of peer-reviewed documents and grey literature.

Results and Discussion

Definitions of Workplace Fatigue

A review of the literature found that there was no consensus on the definition of workplace fatigue and that it is a multidimensional construct. To harmonize discussions, research has proposed that fatigue be viewed from several different dimensions including the origin of fatigue, the biological state of fatigue, and the potential consequences or outcomes of being fatigued. There are few examples of enforced fatigue management standards in general, and limits to clinician work hours are often left to an individual's own judgement.

A review of nine Canadian guidance documents demonstrated that the definition of fatigue varies depending on the type of industry and associated tasks. However, there were causal factors (i.e. physical, mental, sleep, health and emotional), states of fatigue (i.e. subjective, physical and mental) and effects on performance (i.e. physical and mental) that were common to most definitions. These may be considered as a foundational definition for fatigue across all sectors.

Legislation, Best Practices and Guidance

Several international jurisdictions, including Australia, the United States (US) and South Africa have conducted reviews of legislation and best practices on workplace fatigue. There are a few Canadian federal, provincial or territorial regulations related to fatigue that have been developed. Canadian industries that are regulated (e.g. motor carriers, aviation, rail, marine and nuclear) have more comprehensive guidance than non-regulated industries to help address the requirements.

Extensive best practices and guidance have also been developed for some Canadian non-regulated industry sectors (e.g. oil and gas, healthcare, defence). Other industry sectors in Canada that had little or no guidance often relied on international guidance documents in the industry sector, or general guidance that was non-industry specific. Several national and provincial agencies promote sleep education and fatigue awareness for all Canadians, regardless of the industry sector. General guidance on fatigue risk management also exists in many countries outside of Canada, including the US, United Kingdom (UK), Australia, New Zealand and Singapore.

Most Canadian organizations follow federal hours of service (HoS), employment standards code, or provincial worker compensation regulations. A review of the literature indicated that prescriptive HoS were deemed insufficient and that the addition of more comprehensive fatigue management strategies is required [3,5].

Across industry sectors, there were many commonalities in the key content of fatigue management guidance documents, suggesting that there are programmatic elements and tactical approaches that can span all industries. There was a large gap to be filled in providing identification, assessment and mitigation tools where no guidance documents exist or where smaller employers have limited resources. There may be an opportunity to leverage existing standards (e.g. hazard identification and risk assessment) to address workplace fatigue.

Approaches for Managing Workplace Fatigue

Few companies have published or shared details of their fatigue management approaches, resulting in a dearth of research on the efficacy of fatigue risk management initiatives. The practices currently in use in Canada can be grouped into three types of approaches:

1. Prescriptive Rules (e.g. hours of service rules/restrictions);
2. Tactical Approaches (e.g. short duration initiatives that may be part of a larger strategy);
3. Strategic Approaches (e.g. Fatigue Risk Management Systems (FRMS), Fatigue Risk Management Plans, or Fatigue Management Programs that consist of several tactics).

Education and Training

Education is necessary to impart knowledge about the impact of fatigue and to foster the awareness needed for organizational change in integrating fatigue risk management. Training is required to provide the skills needed to identify hazards, control risk, and develop and implement a FRMS. An environmental scan was completed to review education programs and training frameworks currently being used by Canadian workplaces to address fatigue. Education and training approaches of five Canadian government and industry associations were selected because of their detailed approaches to the delivery of education and training across all levels of an organization.

Common educational content and training approaches were found across all of the agencies reviewed, however the method of delivery and amount of content varied. While some companies recommended the use of a qualified trainer, few had identified the prerequisites necessary to evaluate trainer qualifications.

Canadian Workplace Considerations

Two fatigue-related risks warrant potential special consideration for Canadian workers. These include remote working locations (i.e. fly-in/fly-out (FIFO)) and remote lodgings (including sleeping away from home). These conditions should be recognized as factors to consider and address in the overall approach to managing fatigue, as well as in training and education segments.

Conclusions

This report synthesizes the available evidence from the literature and environmental scan to define workplace fatigue and identify existing national and international legislation and best practices related to workplace fatigue. The development of a national standard or standards-based solution may help to address gaps in the existing legislation, industry standards and guidance documents.

"People are experiencing unprecedented levels of workplace fatigue due to....work, societal and personal pressures..."

1 Introduction

People are experiencing unprecedented levels of workplace fatigue due to a combination of modern day work, societal and personal pressures that may include high physical or mental workloads, long work hours, circadian disruptions from work schedule, and inadequate restorative sleep [1-4]. A Statistics Canada study released in 2017 revealed that about a third of Canadian adults slept less than the recommended 7 to 9 hours per night [6]. According to the Transportation Safety Board (TSB) of Canada, one potential outcome of fatigue is the degradation of human performance, thereby increasing risk levels and subsequently leading to errors, incidents and accidents [7]. The TSB released its "Watchlist" in 2018, citing employee fatigue as "a major safety hazard" for all transportation modes. During a review of the investigation reports accumulated since 1992, the TSB was able to establish that fatigue was at least a contributing if not causal factor in over 90 of the incidents, citing long hours, erratic schedules and the crossing of time zones as some of the key determinants [7]. Other researchers have also linked fatigue to accident causation [8-9].

There is inconsistency in the definition of fatigue, but it is typically referred to as a lack of alertness [10-11] and attention [12] that is associated with decrements in cognitive ability [13-14] and physical performance [14-15]. While there are several potential causes of fatigue, health and safety guidance prioritizes aspects associated with sleep loss [16], extended wakefulness [15], circadian rhythm phase [8], physical workload [13] or mental workload [15].

National and international agencies are addressing fatigue through a range of activities including education and training, research, and implementing hours of service (HoS) legislation. These strategies remain intact and are beneficial for mitigating fatigue across high-risk sectors such as transportation, nuclear, and energy [17]. While guidance exists for some industry sectors, guidance that addresses commonalities across all industries has not been established.

1.1. Objective

The purpose of this report is to:

- Synthesize available evidence from the literature and environmental scan to define workplace fatigue and identify existing national and international legislation and best practices related to workplace fatigue;
- Identify promising practices for Canadian workplaces; and
- Provide a gap analysis detailing the need for a national standard or other standards-based solutions (e.g., training, assessment tools, guidelines, etc.) on fatigue risk management, with examples from various key Canadian sectors.

The following research questions guided this work:

- What is the definition of "workplace fatigue"?
- What Canadian (federal/provincial/territorial) legislation is available to address workplace fatigue?
- What are the recognized international best practices for workplace policies and government regulations?
- What are best practices regarding fatigue risk management?
- How is fatigue being assessed when performing hazard (risk) analysis?
- What education programs/training frameworks are currently being used by workplaces to address fatigue?
- What are the recommended approaches for managing workplace fatigue in Canadian workplaces?

1.2. Scope

This report provides a summary of the research and practice-based evidence on workplace fatigue risk management, and identifies best and emerging practices where available. It does not provide detailed guidance on specific issues such as sleep science, identification and assessment of fatigue-related risk, or shift scheduling. An analysis of a range of industry sectors was sought, though an in-depth exploration of how specific sectors have addressed the issue of workplace fatigue is beyond the scope of this report.

2 Methods

A literature review and environmental scan were used to gather information related to workplace fatigue. The literature review involved searches in online (e.g. Google Scholar) and library-based (University of Calgary) academic repositories that included peer-reviewed documents from Canada and other major developed countries. Relevant databases included NIOSHTIC2, SafetyLit, Embase and MEDLINE®.

To obtain more information on approaches not addressed in the academic literature, and to see how fatigue risk management was practiced within and outside of Canada, searches were conducted of the grey literature using Google as the primary search engine. Grey literature included government publications, regulatory documents, conference presentations and proceedings, dissertations, and white papers over the past 5 years. A series of pre-defined search terms (Table 1) related to the research questions.

Potentially relevant articles were identified by scanning titles, abstracts, and citations. Previous literature reviews and research summaries were prioritized to help consolidate the broad range of research and approaches related to fatigue risk management. Electronic database bibliography software (i.e. Mendeley) was used to warehouse, share and review references in a common database.

3 Results and Discussion

3.1. Definitions of Workplace Fatigue

Defining workplace fatigue can be challenging given it can be interpreted from several different perspectives including quantity and quality of sleep, physical workload, mental stress, chronic medical conditions, fitness for duty, and impairment. While many definitions of fatigue have been proposed, there is no consensus view at present. These varied viewpoints demonstrate the complex nature of fatigue as a concept [18].

A distinction exists in the literature between fatigue as an objective state and the subjective feelings of sleepiness or drowsiness. This clarification may be an important aspect to include when defining fatigue to help distinguish between a form of exertion and a state of tiredness. Lerman et al. [19] define fatigue as the body's natural reaction to physical/mental exertion or sleep deprivation, while sleepiness refers to how inclined we are to fall asleep.

Discussions that were themed from a workshop on managing fatigue in the extractive industries expanded

Table 1: *Search Terms*

Domain	Terms	
Place	(workplace OR "work environment") AND	
Action	(fatigue or alertness or sleepiness) AND	
Intervention	(policy OR guideline OR program OR procedure OR "management system" OR "best practice" OR "risk assessment" OR training OR education OR "standard"	
Sectors	transportation road OR traffic aviation rail marine nuclear extractive OR "oil and gas" OR pipeline OR mining healthcare OR nursing OR physician defence OR military EMS OR paramedic OR "emergency management" firefighter agriculture	forestry manufacturing "performance arts" OR film OR performers OR actors chemical construction education hospitality telecommunications utilities OR electricity insurance OR financial law OR police municipality

on the definition of fatigue to state that, "fatigue results from insufficient sleep, working when you would normally be asleep (according to one's circadian rhythms), and prolonged hours of work" [20]. This definition adds circadian rhythms as a key component. However, there was disagreement on the extent to which physiological conditions [i.e. physical] cause fatigue.

Phillips [21-22] completed a review of fatigue definitions to summarize this complex concept. Table 2 shows the different definitions of fatigue grouped according to type. Definitions of fatigue could be categorized as:

- An experience (i.e. subjective/experiential);
- A physiological condition (i.e. a state of weakness or depletions resulting from exertion);
- A physiological performance decrement;
- A performance decrement with effects on multiple performance outputs; and
- A multidimensional construct (i.e. aspects of experience, physiology or performance) [21-22].

Phillips stated that "delimiting the origins, state and consequences of fatigue" would help to make the measures of fatigue more explicit. This would provide a whole definition of fatigue that would clearly identify the aspects of fatigue that are measured or not measured within various studies. Phillips proposed that fatigue should first be framed as a state or condition resulting from a specific type of exertion, referring to either active or passive task-related fatigue, or sleep-related fatigue. From there, it can be categorized into the context of a physiological state (e.g., sleepiness, physically tired, mentally fatigued), which could then identify potential performance outcomes (e.g., decreased reaction time, reduced situational awareness) [22].

3.1.1. Canadian Definitions of Workplace Fatigue

An environmental scan of the legislation, best practices and guidance used in Canada were reviewed to investigate the definitions of fatigue employed in Canada. Table 3 lists the definitions used for fatigue and the corresponding source. The associated causal factors, states of fatigue and the performance effects were classified for each definition to assist with a comparative analysis.

Table 2: *Definitions of Fatigue Grouped According to Type. Table Adapted from Phillips [22]*

Category	Example	Source
Dictionary	"…extreme tiredness resulting from mental or physical exertion or illness."	Oxford Dictionaries, 2013 [23]
Subjective	"feeling tired, sleepy or exhausted." "subjectively experienced disinclination to continue performing the task because of perceived reductions in efficiency." "an overwhelming sense of tiredness, lack of energy and a feeling of exhaustion, associated with impaired physical and/or cognitive functioning." "awareness of a decreased capacity for physical and/or mental activity due to imbalance in the availability, use and/or restoration of resources needed to perform an activity."	NASA, 1996 [24], cited in Soames-Job & Dalziel, 2000 [25] Brown, 1995 [26] Shen et al., 2006 [27] Aaronson et al., 1999 [28], cited in Strober & Deluca, 2013 [29]
Physiological	"the state of an organism's muscles, viscera, or CNS, in which prior physical activity and/or mental processing, in the absence of sufficient rest, results in insufficient cellular capacity or system-wide energy to maintain the original level of activity and/or processing by using normal resources." "weakness…from repeated exertion or a decreased response of cells, tissues, or organs after excessive stimulation, stress or activity." "…a change in psychophysiological state due to sustained performance [of one or more tasks at work]."	Soames-Job & Dalziel, 2000 [25] Hirshkowitz, 2013 [30] van der Linden et al., 2003 [31]
Physiological/ performance	"reduced force production, loss of exercise capacity, increased sense of effort or perception of force." "…is the inability to function at the desired level due to incomplete recovery from demands of prior work and other waking activities. Acute fatigue can occur when there is inadequate time to rest and recover from a work period. Cumulative or chronic fatigue occurs when there is insufficient recovery from acute fatigue over time."	Davis & Walsh, 2010 [32] cited in Strober & Deluca, 2013 [29] Gander et al., 2011 [33]
Performance	"measurable decrements in performance of an activity caused by extended time performing it." "a diminished capacity for work and possibly decrements in attention, perception, decision making and skill performance." "decrements in performance on tasks requiring alertness and the manipulation and retrieval of information stored in the memory."	Bartlett, 1953 [34] cited in Gawron et al., 2000 [35] Cercarelli & Ryan, 1996 [12] Gawron et al., 2000 [35]
Multiple	"There are three aspects to fatigue: physiological, objective (work decrement), and subjective fatigue." "A psychophysiological state that occurs when a person is driving and feeling tired or drowsy, to the extent that they have reduced capacity to function, resulting in performance decrements and negative emotions and boredom as they attempt to stay awake during the task."	Bills, 1934 [36] Craig et al., 2011 [37]

"...the definition of fatigue can vary depending on the type of industry and the associated tasks."

All but one definition included at least one causal factor in the definition. The causal factors included:

- **Physical Causes –** physiological activity or demands;
- **Mental Causes –** mental processing or cognitive demands;
- **Sleep Causes –** sleep loss, sleep deprivation (insufficient sleep) or disruption of circadian rhythms;
- **Health Causes –** related to illness, medical conditions or pharmaceuticals; and
- **Emotional Causes –** including stress or anxiety.

Many sources (6/9) included three causal factors related to sleep loss or deprivation, mental demands/activities, and physical/physiological workload [15, 38-42]. Health factors, such as medical conditions or pharmaceuticals, were cited once [7]. Emotional factors, such as anxiety, were identified in 4/9 definitions, which included general occupational health and safety (OHS) as well as the healthcare and defence sectors [38, 39, 41, 42]. These sectors may place more focus on emotional/psychological stress factors given the high intensity and variety of situations experienced that can impact psychological health.

There were three states of fatigue that the definitions focused on:

- **Subjective State –** experiences of feeling tired, drowsy, weary, or sleepy. Includes lethargy.
- **Physical State –** a state of physiological weakness/degradation from exertion. Physically exhausted.
- **Mental State –** a state of reduced mental capacity (for attention, alertness and decision making).

Subjective fatigue was cited in 3/9 definitions [16, 38, 42]. However, it was the sole state described by the Canadian Centre for Occupational Health and Safety (CCOHS) [38]. Both physical and mental states of fatigue were included in a majority (8/9) of definitions [10, 13, 15-16, 39-42].

There were two effects on performance noted:

- **Physical Performance –** effects on functioning and task performance; and
- **Mental Performance –** effects on alertness and cognitive performance.

Effects on both physical and mental performance were cited by a majority (7/9) of definitions [10, 13, 15-16, 39, 40, 42].

3.1.2. Defining Workplace Fatigue

Due to a lack of consensus on the definition of fatigue and the multidimensional nature of the issue, a comprehensive definition that includes the origin (i.e. causes), state (i.e. resulting condition), and consequences (i.e. performance effects) of fatigue relative to a specific industry sector may have more value in guiding both researchers and organizations in a path forward.

Table 3 – *Canadian Definitions of Workplace Fatigue*

Source & Industry	Definition of Fatigue	Causal Factors	States of Fatigue	Performance Affected
CCOHS [38]	"Fatigue is the state of feeling very tired, weary or sleepy resulting from insufficient sleep, prolonged mental or physical work, or extended periods of stress or anxiety. Boring or repetitive tasks can intensify feelings of fatigue. Fatigue can be described as either acute or chronic."	Sleep Mental Physical Emotional	Subjective	—
North American Fatigue Management Program – Motor Carriers [16]	"Fatigue can best be defined as combinations of symptoms that include mental and physical elements, impaired performance, and subjective feelings of alertness. There are two types of fatigue: 1) acute, or short-term, fatigue; and 2) chronic, or long term, fatigue."	—	Subjective Mental Physical	Physical Mental
Energy Safety Canada [ENFORM]– Oil and Gas – Upstream [10]	"State of reduced mental and physical alertness or functioning caused by sleep related disruption or deprivation as a result of extended work hours, insufficient sleep, or the effects of sleep disorders, medical conditions or pharmaceuticals which reduce sleep or increase drowsiness."	Sleep Health	Mental Physical	Mental (alertness) Physical (functioning)
Transport Canada – Aviation [15]	"ICAO defines fatigue as a physiological state of reduced mental or physical performance capability resulting from sleep loss or extended wakefulness, circadian phase, or workload (mental and/or physical activity) that can impair a flight crew member's alertness and ability to safely operate an aircraft or perform safety-related duties."	Mental Physical Sleep	Mental Physical	Mental (alertness) Physical
Transport Canada– Rail [13]	"(Physical) Physical discomfort from overworking a group of muscles." "(Mental) Difficulty concentrating, difficulty processing important signals, and problems staying awake in critical situations. Fatigue can cause the impairment of physiological and/or cognitive performance."	Physical Mental	Physical Mental	Mental Physical
Transport Canada – Marine [39]	"Fatigue can be defined as a progressive loss of mental and physical alertness that can end in sleep. Physical fatigue usually occurs after strenuous physical activity or very long periods of activity. Lack of sleep and/or sleeping at a different time of the day, or mental stress or high mental workload will quickly result in mental fatigue."	Physical Mental Sleep Emotional	Physical Mental	Mental (alertness) Physical
CNSC – Nuclear [40]	"Worker fatigue is a state of reduced mental or physical performance capability resulting from sleep loss, extended wakefulness, phase of the circadian rhythm or workload. As fatigue increases, declines occur in many aspects of human performance, especially alertness. Alertness is fundamental to many cognitive tasks."	Sleep Mental Physical	Physical Mental	Mental (alertness)
DRDC – Defence [41]	"Fatigue includes physiological fatigue as a result of prolonged physical work, continuous operations, acute and cumulative sleep deprivation, sleep disruption…" "Mental fatigue can be defined as a psychological state caused by prolonged periods of demanding mental activity/ stress, extended periods of anxiety, and long durations of boring monotonous tasks."	Physical Sleep Mental Emotional	Physical Mental	

Continued on next page >

RNAO/CNA – Nursing [42]	"A subjective feeling of tiredness (experienced by nurses) that is physically and mentally penetrative. It ranges from tiredness to exhaustion, creating an unrelenting overall condition that interferes with individuals' physical and cognitive ability to function to their normal capacity. It is multidimensional in both its causes and manifestations; it is influenced by many factors: physiological (e.g. circadian rhythm), psychological (e.g. stress, alertness, sleepiness), behavioural (e.g. pattern of work, sleep habits) and environmental (e.g. work demand). Its experience involves some combination of features: physical (e.g. sleepiness) and psychological (e.g. compassion fatigue, emotional exhaustion). It may significantly interfere with functioning and may persist despite periods of rest."	Sleep Mental Physical Emotional	Subjective Mental Physical	Mental Physical
Abbreviations:	CCOHS Canadian Center for Occupational Health and Safety CNA Canadian Nurses Association CNSC Canadian Nuclear Safety Commission DRDC Defence Research and Development Canada ICAO International Civial Aviation Organization RNAO Registered Nurses' Association of Ontario			

According to the Canadian guidance documents reviewed in Table 3, the definition of fatigue can vary depending on the type of industry and the associated tasks. Table 4 illustrates terms for consideration, which may be included when developing a foundational definition for fatigue across all sectors. The terms cited most often are identified with an asterisk. A global definition spanning several industries may include several of these terms to demonstrate the complexity and multifaceted nature of fatigue.

3.2. Legislation, Best Practices and Guidance

3.2.1. International Legislation and Regulations on Workplace Fatigue

Research has been conducted in a variety of international jurisdictions, such as Australia, the US and South Africa to review, summarize and evaluate key aspects of legislation and best practices on workplace fatigue.

The Australian Safety and Compensation Council (ASCC) summarized recent regulatory developments in workplace fatigue in 2006 [43]. The review provides a snapshot of regulations in Australia as well as international activities related to transportation, health services and other high-risk sectors. The findings highlighted that regulations focused on the restriction of hours of work, but there was an increasing interest in the use of fatigue management programs (FMP) for supplementing prescriptive hours of work regulations.

Organizational factors impacting fatigue risk management at the regulatory and industry/company level have been investigated, with a focus on the transportation sector [33]. Gander et al. [33] traced the evolution of international regulatory frameworks from HoS regulations through to fatigue risk management system (FRMS) frameworks in several developed nations including the US, Canada, the United Kingdom, Australia and New Zealand. It is suggested that, by moving toward an FRMS approach, there is a consequent shift away from regulatory compliance to a risk-based approach that focuses on the organization's role (both employers and employees) in effective, ongoing management of fatigue-related risk. The research further advocates for sharing experiences between all stakeholders (regulators, employers, employees) wherever possible, and the necessity of all to understand not only the causes and consequences of fatigue, but their specific responsibilities in relation to mitigating risk.

Fatigue management lessons from international legislation and practice were also investigated by

Table 4 – *Examples of Terminology for Defining Fatigue*

Origins/Causal Factors	States	Consequences
Sleep Causes* ▪ lack of sleep ▪ sleep deprivation/loss ▪ extended wakefulness ▪ disruption of circadian rhythms **Mental Causes*** ▪ mental processing ▪ cognitive demands ▪ overload **Physical Causes*** ▪ physiological exertion ▪ physical activity/demands ▪ inadequate rest ▪ overwork **Health Causes** ▪ illness ▪ medical conditions ▪ pharmaceuticals **Emotional Causes** ▪ stress ▪ anxiety	**Mental State*** ▪ reduced mental capacity ▪ inattentive ▪ indecisive **Physical State*** ▪ physiological weakness/degradation ▪ physically exhausted ▪ weak **Subjective State** ▪ tired ▪ drowsy ▪ weary ▪ sleepy ▪ lethargic	**Mental Performance*** – effects on alertness and cognitive performance ▪ impaired mental capacity ▪ lack of alertness ▪ diminished cognitive processing ▪ loss of situational awareness ▪ impaired driving performance ▪ impaired cognitive performance **Physical Performance*** – effects on functioning and task performance ▪ impaired physical capacity ▪ performance impairment ▪ reduced work capabilities ▪ impaired job/task performance

**Commonly addressed terms*

researchers in South Africa in 2015 [18]. The review focused on road transportation and traffic legislation, as well as methods of fatigue detection. The research noted international efforts to address fatigue through traffic legislation and to develop new ways of operationalizing fatigue as a prosecutable traffic offence. However, the difficultly in diagnosing fatigue made it challenging to both prosecute and define fatigue as an offence under traffic legislation [18].

In New Jersey, 'Maggie's Law' was the first piece of legislation in the United States that clearly laid out prosecutorial charges for fatigue-related crashes [44]. Under this law, fatigue is defined as, "being without sleep for more than 24 consecutive hours prior to the accident" [45] and drivers can be convicted of vehicular homicide. The legislation was based on scientific evidence that correlated sleep deprivation with driver competence and performance impairment. The research equated the number of hours of wakefulness with equivalent blood alcohol concentrations (BAC) where being awake for 18 hours produced simulated driving performance impairments equal to 0.05% BAC. Being awake for 21 hours produced impairments similar to 0.08% BAC [46]. A separate study found that, at 24 hours of wakefulness, performance impairment levels were equal to 0.10% BAC [47].

Only one other state, Arkansas, adopted this legislation, possibly indicating the difficulty linking lack of sleep to performance impairment. Other states assert that fatigue be addressed under existing legislation for reckless driving and vehicular homicide laws. Indeed, police officers have reported difficulties in identifying sleepiness as a contributing factor to crashes [48].

"Eight industry sectors in Canada... have extensive guidance on workplace fatigue."

Work regulations in the US were also recently reviewed by Caldwell et al. [3]. This review indicated that there were no general regulations in the US, aside from work-hour regulations imposed by federal and state statutes for pilots, truckers and nurses, for mitigating the effects of shiftwork on cognitive performance or physical and mental fatigue.

3.2.2. Canadian Legislation and Regulations on Workplace Fatigue

An environmental scan identified few federal, provincial or territorial regulations related to fatigue in Canada. Each jurisdiction in Canada outlines the requirements for days of rest, daily maximum hours and rest periods for all regulated employees. Some industries, such as the nuclear, aviation and commercial trucking sectors, have industry-specific regulations. Sector-specific legislation, best practices and guidance are presented in Section 3.2.3.

No direct reference to fatigue was found in provincial workers compensation acts or in the federal OHS act. However, Saskatchewan was one of the first provinces to recognize the need to manage the effects of shift work, as per Part VI (82) of the *Occupational Health and Safety Regulations* [49].

In Canada, eleven of thirteen provinces and territories offer Certification of Recognition (COR) programs, an auditable process that rewards employers for meeting COR program standards based on the development and integration of an occupational health and safety management system (OHSMS). Of all the Canadian jurisdictions, only British Columbia advocates the importance of including fatigue as a potential hazard in their COR program [50].

3.2.3. Industry-Specific Guidance on Workplace Fatigue

The environmental scan identified fatigue risk management guidance for many industries/sectors in Canada and internationally. Eight industry sectors in Canada were identified to have extensive guidance on workplace fatigue. These sectors include:

- Motor Carriers;
- Aviation;
- Rail;
- Marine;
- Nuclear;
- Oil and Gas;
- Healthcare; and
- Defence.

Table 5 provides a summary of each industry sector and the associated legislation, best practices and guidance. Further discussion is provided in Appendix A.1. Other

Table 5 – *Summary of Canadian and International Legislation, Best Practices and Guidance on Workplace Fatigue*

	Motor Carriers	Aviation	Rail	Marine	Nuclear	Oil and Gas	Healthcare	Defence
Canadian Legislation and Regulations	▪ ***Federal Commercial Vehicle Drivers HoS Regulations:*** [51] ▪ ***Motor Vehicle Transport Act:*** requires recording equipment/ logbooks [52]	▪ ***Canadian Aviation Regulations:*** requires work/ rest restrictions and provides an alternative to set up a FRMS [54]	▪ ***Railway Safety Act:*** Work/Rest Rules: includes rest periods, duty limits, and requirements for FMPs [58]	▪ ***Marine Personnel Regulations (section 320):*** includes work/ rest restrictions [61]	▪ ***CNSC REGDOC-2.2.4 Fitness for Duty: Managing Worker Fatigue:*** includes limits on work/ rest and requirements for program elements [40]	No Canadian Regulations	No Canadian Regulations	No Canadian Regulations
Canadian Best Practices & Guidance Documents	▪ ***NAFMP:*** includes online training modules, sleep disorder screening practice, and guidance on fatigue monitoring technologies [16]	▪ ***TC FRMS Toolkit:*** includes audit tool and aviation-related fatigue risk management controls [55]	▪ ***TC Fatigue Management Plans:*** Requirements and Assessment Guidelines: considers sleep environments [13]	▪ ***FM Program for Canadian Marine Pilots:*** includes implementation plan, training and scheduling guidance [39,62]	▪ ***CNSC REGDOC-2.2.4:*** includes program elements specific to roles and responsibilities; shift schedules; training topics, fatigue risk assessment and continuous improvement [40]	▪ ***CAPP Code of Practice-Fatigue Management*** [69] ▪ ***Energy Safety Canada - FRM Program Dev. Guide:*** includes scalable program depending on size/ characteristics of the organization [10] ▪ ***CSA Group-Pipeline Human Factors*** [70]	▪ ***CMA Management of Physician Fatigue*** [78] ▪ ***CNA Nurse Fatigue and Patient Safety*** [14] ▪ ***RNAO Preventing and Mitigating Nurse Fatigue in Health Care*** [42] ▪ ***FRM Toolkit for Residents, Leaders and Policy Makers:*** includes training and guiding principles [79]	▪ ***DRDC – General Recommendations on Fatigue Risk Management for the Canadian Forces [41]***
International Guidance & Legislation	▪ ***Maggie's Law (US):*** addresses reckless driving due to sleep-deprivation [45] ▪ ***Heavy Vehicle National Law (AU):*** requires drivers to evaluate risk of work/rest schedule [53] ▪ ***Chain of Responsibility (AU/NZ):*** potential offences if driver breaches HoS limits [33]	▪ ***ICAO, IATA & IFALPA FRMS Guide/Manual for Operators and Regulators (International):*** ICAO has FTLs and a framework for regulators to oversee an FRMS [56] ▪ ***EASA (Europe):*** requires SMS and fatigue risk mgt [57]	▪ ***FRA (US):*** requires analysis of work schedules using biomathematical fatigue modelling. [59] ▪***Railroaders' Guide to Healthy Sleep (US):*** an online resource to provide awareness information and screening tools [60]	▪ ***IMO:*** guidance material for fatigue mitigation and management [63] ▪ ***US Coast Guard Crew Endurance Management System*** [64] ▪ ***US FRM Plan for Towing Vessel Operators*** [65]	▪ ***US 10 Code of Federal Regulations (CFR) Pt. 26*** [66] ▪ ***USNRC Reg. Guide 5.73 - "Fatigue Management for Nuclear Plant Personnel"*** [67] ▪ ***NEI 06-11 [Rev 1](US) - "Managing Personnel Fatigue at Nuclear Power Reactor Sites"*** [68]	▪ ***IPIECA/IOGP:*** guidance on managing fatigue, perf. indicators for FRMS, assessing risks and fly-in, fly-out ops. [71-74] ▪ ***Energy Institute (UK):*** guidance on FRM plan [75] ▪ ***ANSI (US):*** Rec. Practice 755 on FRMS [76] ▪ ***PHMSA (US):*** requires measures to prevent fatigue of operators [77]	None identified	▪ ***US Army – "Combat and operational stress control manual for leaders and soldiers"*** [80] ▪ ***AU Forces - "Fatigue Management during Operations- A Commander's Guide"*** [81]
Canadian Fatigue Hazard ID and Risk Assessment	▪ ***NAFMP:*** includes sleep disorder screening tools and program [16]	▪ ***TC FRMS Toolkit:*** includes schedule analysis tools and fatigue calculator [55]	No industry-specific assessment tools	No industry-specific assessment tools	No industry-specific assessment tools	***Energy Safety Canada – FRM Program Dev. Guide:*** includes fatigue calculator (wallet card)	***FRM Toolkit:*** includes schedule assessment [79]	No industry-specific assessment tools
Abbreviations:	**ANSI** American National Standards Institute **AU** Australia **CAPP** Canadian Association of Petroleum Producers **CFR** Code of Federal Regulations **CMA** Canadian Medical Association **CNA** Canadian Nursing Association **CNSC** Canadian Nuclear Safety Commission **CSA** Canadian Standards Association **DRDC** Defence Research and Development Canada **EASA** European Union Aviation Safety Agency		**ESC** Energy Safety Canada **FAA** Federal Aviation Administration **FM** Fatigue Management **FMP** Fatigue Management Plan **FRA** Federal Railroad Administration **FRM** Fatigue Risk Management **FRMS** Fatigue Risk Management System **FTL** Flight Time Limitations **HoS** Hours of Service **IATA** International Air Transport Association		**ICAO** International Civil Aviation Organization **IFALPA** International Federation of Air Line Pilots' Associations **IMO** International Maritime Organization **IOGP** International Association of Oil & Gas Producers **IPIECA** International Petroleum Industry Environmental Conservation Association **NAFMP** North American Fatigue Management Program **NEI** Nuclear Energy Institute **NJ** New Jersey **NZ** New Zealand		**PHMSA** Pipeline and Hazardous Materials Safety Association **RNA** Registered Nurses Association of Ontario **RP** Recommended Practice **SMS** Safety Management System **TC** Transport Canada **TSB** Transportation Safety Board **UK** United Kingdom **US** United States of America **USNRC** United States Nuclear Regulatory Commission	

**Commonly addressed terms*

industry sectors that had less extensive legislation, best practices and guidance to address workplace fatigue are reviewed in Section A.2.

3.2.4. General International Guidance on Workplace Fatigue

General guidance on fatigue risk management exists in many countries, including the US, UK, Australia, New Zealand and Singapore.

Several US national organizations have focused on the topic of fatigue in the US, including the National Safety Council (NSC), the US Department of Labor, and the Centers for Disease Control and Prevention (CDC).

- The NSC conducted a Fatigue Blue Ribbon Panel meeting in December 2016 and completed a National Employee Survey on Workplace Fatigue in 2017 [82]. Since then, they have issued a three-part series on Fatigue in the Workplace focusing on:
  - causes and consequences of employee fatigue [83];
  - the impact, risk and recommendations for fatigue in safety critical industries [84]; and
  - risky employer practices [85].

  They have also released a brief literature review on the concept of FRMS [86] and have been running a series of informational sessions and workshops led by invited fatigue specialists, including a Workplace Fatigue Conference held in February 2019. Additional resources include an NSC Fatigue Cost Calculator [87] and a report on "Understanding Fatigue Risk: Assessment and Countermeasures" [88]. The report outlines a fatigue initiative pilot study that utilized a needs assessment approach to collect data on sources of fatigue in the workplace from both an employer and employee perspective.

- The US Department of Labor – Occupational Safety and Health Administration (OSHA) provides awareness information on "Long Work Hours, Extended or Irregular Shifts, and Worker Fatigue" [89]. This information outlines the hazards and prevention strategies, including a Fatigue Risk Management Program, for employers and employees. Links to US limitations on work hours are provided for nursing, aviation, motor vehicle drivers, railroad employees, seafarers and nuclear facilities.

- The CDC and National Institute for Occupational Safety and Health (NIOSH) provide guidance, links to conferences, links to help find sleep disorders specialist/centres, resources for researchers and scientists, webinars, educational resources for managers and workers, scientific publications, selected scientific publications on strategies for coping, and general information about sleep [90]. Training resources are available online for nurses, emergency responders, and commercial pilots.

In the UK, the Health and Safety Executive (HSE) provides guidance on fatigue as a human factor topic [91]. This includes a publication entitled "Health and safety guidance: Managing shift work", which outlines health and safety guidance. Another publication entitled "Managing "Managing shift work" outlines legal responsibilities of the employer and provides content to improve the understanding of fatigue and shift work operations. It also encourages a fatigue risk management process (ASSESS-ACT-CHECK-REVIEW), which synchronizes with the PLAN-DO-CHECK-ACT model referenced in many safety management systems (SMS) standards including Canada's CSA Z1000 series [92]. Links are provided to guidance that is targeted to specific industries (i.e. rail, offshore). Content also includes briefing notes with awareness information, case studies, and key principles on fatigue.

Australia has several guidance documents that apply generally across all sectors. Safe Work Australia (SWA), an Australian Government statutory agency, developed guidance in 2013 for workers and employers [93]. Other resources include an overview of fatigue, links to guidance documents, research reports and case studies, and videos [94]. As SWA is not a regulator, each state and territory's work health and safety authority developed their own fatigue management advice. Examples include WorkSafe Victoria's "Fatigue prevention in the workplace" guidance [95] and Northern Territory (NT) WorkSafe's bulletin on "Managing the risk of fatigue" [96]. The Residential Tenancies Authority developed a fatigue management procedure to align with the 2001 Occupational Health and Safety Regulation [97]. They present a risk-based approach that outlines the identification, assessment and control of fatigue-related risks followed with steps to review and monitor risk assessment performance.

"Several national and provincial agencies promote sleep education and fatigue awareness for all Canadians, regardless of the industry sector."

In 2007, New Zealand's Department of Labour (DoL) provided a guide for employers on "Managing shift work to minimize workplace fatigue." The document highlighted key facts about fatigue and its implications for employers, as well as a framework for managing workplace fatigue that includes strategies for small employers [98]. The DoL has since been integrated into WorkSafe New Zealand which now provides fatigue management support in the form of quick guides, videos, posters, and advice for both small business owners and workers [99].

Singapore's Workplace Safety and Health Council (WSHCouncil) developed "Workplace safety and health guidelines: fatigue management" to inform industries on how to establish a fatigue management process with emphasis on customizing policies and procedures specific to each organization's operational needs and work environment [100].

3.2.5. General Canadian Guidance on Workplace Fatigue

Several national and provincial agencies promote sleep education and fatigue awareness for all Canadians, regardless of the industry sector. The CCOHS has a variety of products intended to raise awareness of fatigue. These include fact sheets ("Extended Workday: Health and Safety Issues) [38,101], infographics, and podcasts (e.g. "Health and Safety To Go - Preventing Health Risks Associated with Shiftwork") [102]. The Canada Safety Council provides tips to avoid drowsy driving, as well as general awareness of fatigue related to workplace safety [103].

The Canadian Cancer Society provides information related to fatigue as a side effect of cancer. The materials provide content on the causes, symptoms, diagnosis and strategies for managing fatigue. Further, the Occupational Cancer Research Centre provides a knowledge synthesis of their study on shiftwork in Canadian industries with the goal of raising awareness of shiftwork as a probable cancer risk factor and identifying practical interventions that can be used in workplaces to reduce the negative health effects of shiftwork [104].

During 2015-2016, Ontario's Public Services Health and Safety Association (PSHSA) conducted research that relied on data derived from wearable wrist-worn technology designed to monitor sleep, activity and fatigue. The intent was to gain an understanding of fatigue's impact and subsequently, identify preventative measures for the workplace. As an outcome of their research, the PSHSA offers "a Fatigue Management Program as a turnkey solution, based on scientific evidence" and provides a menu of options – from building awareness to implementing a complete fatigue risk management program. Online resources include an infographic ("How does fatigue affect safety?"), video, and study results linking night and evening shifts to higher risk of injuries [105].

The Alberta government provides OHS information and quick facts for workers and employers on the topics of fatigue, extended work hours and workplace safety. A study completed on "Fatigue, Extended Work Hours, and Safety in the Workplace" is often referenced by other government organizations [106]. The Alberta Ministry of Labour links to an online course on Shift Work and Fatigue [107].

In BC, WorkSafeBC provides information to address the topic of fatigue. This includes human factors bulletins on "Work schedules and fatigue" and "The dangers of fatigue in the workplace" [50,108]. WorkSafeBC also has several initiatives to drive fatigue management. These include a review of compliance initiatives directing employers to implement a system, plan or process to reduce the risk of worker fatigue. WorkSafeBC has also hosted education sessions and symposiums related to fatigue and is sponsoring a research review.

3.2.6. Summary of Legislation, Best Practices and Guidance

Most Canadian organizations follow federal HoS, provincial employment standards codes, or provincial worker compensation regulations to address fatigue-related risk. A review of the literature indicated that many international jurisdictions began with prescriptive HoS, but experienced difficulties in realizing the benefits and establishing the required resources to enforce them. As a result, more comprehensive fatigue management strategies were sought to manage fatigue-related risk.

Regulated industries in Canada (e.g. motor carriers, aviation, rail, marine and nuclear) have access to guidance to address fatigue-related regulations, including guidance developed in Canada and internationally. Much of the Canadian guidance has leveraged international best practice.

Across industry sectors, there were many commonalities in the key content of fatigue management guidance documents. For example, the structure of an FRMS was similar between the oil and gas industry and aviation. This suggests that there are programmatic elements and tactical approaches that can span all industries. Larger industry sectors have adopted tactical strategies customized for the nature of the tasks and risk associated within their operations, incorporating their internal lexicon and customized case studies that were appropriate for the industry taxonomy.

Gaps exist in providing customized guidance to stakeholders for specific industries given the unique challenges and industry-specific terminology. There was a large gap to be filled in providing identification, assessment and mitigation tools where no guidance documents exist, or where smaller employers have limited resources. The review indicates that procedures could be further developed to address fatigue as a hazard that is assessed and controlled as part of a hazard identification and risk assessment process. A risk management standard (such as ISO 31000 [109]) could provide the basis for a risk-based approach to fatigue. A risk-based approach essentially tailors the management process to the context within which the risk manifests. Existing Canadian OHS and risk management standards could be leveraged to establish ways to identify fatigue, assess the risk, develop control measures, and review/monitor the risks.

3.3. Approaches for Managing Workplace Fatigue

Few companies have published or shared details of their fatigue management approaches, resulting in a dearth of research on the efficacy of fatigue risk management initiatives. An environmental scan identified case studies and conference presentations from organizations on their approach to managing workplace fatigue and on lessons learned. However, these lacked objective metrics to demonstrate the effectiveness of the methods.

In 2011, the International Council on Mining and Metals (ICMM), International Association of Oil and Gas Producers (IOGP), and International Petroleum Industry Environmental Conservation Association (IPIECA) held a workshop on managing fatigue in the extractive industries [20]. Although targeted to the extractive industries, the themes that emerged were similar to those expressed by other organizations that have explored workplace fatigue management. From this workshop, five main themes emerged relating to fatigue management:

1. The need for customization: A multidisciplinary approach is required to account for the numerous components that constitute fatigue management. The approach must consider existing governance systems,

tailored communications, the appropriateness and associated risks/challenges of technology and tools, a variety of hazards that affect fatigue-related risk, and the maturity of the organizational culture to acknowledge and address fatigue.

2. Success depends on full engagement: Engagement is required to build relationships, break down barriers to communication and understanding, and empower all levels (industry-wide, leadership, individuals, and families/communities). Data is a key component of driving change and validating efforts.

3. Fatigue is a complex issue: The nature of fatigue makes it difficult to define and measure. The effects of fatigue can vary and can be affected by many different factors, including culture.

4. A systems response is necessary but not enough to manage fatigue: Emphasis here is on the integration of a risk-based approach to managing fatigue that is tailored to the operational context of the work being performed. Two approaches are discussed; the first is a multi-layered approach (commonly referred to as the "Swiss Cheese" model) that focuses on various levels of defence, while the second reflects a scalable maturity model with efforts to mitigate risk based on defined stages of organizational and cultural maturity. Regardless of the methodology selected, fatigue management will still require dependence on individual behaviours at all levels, especially at the supervisory level.

5. Guidance is required: Additional guidance would be useful if it is sector specific, with industry-specific examples and issues. It should also go beyond the sharing of information and provide action-oriented guidance (at the level of site management).

Generally, practices currently in use in Canada can be grouped into three types of approaches:

1. Prescriptive Rules (e.g. HoS rules/restrictions);
2. Tactical Approaches – short duration initiatives that may be part of a larger strategy; and
3. Strategic Approaches – larger, overall plans or programs that may include several tactics (e.g. FRMSs, Fatigue Risk Management Plans, FMPs).

3.3.1. Prescriptive Rules

As previously discussed, many industry sectors have prescriptive HoS regulations to minimize workplace fatigue. Prescriptive HoS regulations have been active for several years for road transportation (heavy vehicles), however a review of these regulations by the Canadian Council of Motor Transport Administrators [110] recommended that HoS be part of a comprehensive fatigue management strategy that is recognized and endorsed by industry and governments.

Further, a Transport Canada report studying air traffic controller fatigue [5] highlighted that, "due to the complex array of variables that influence a person's ability to function at an optimal level it is extremely unrealistic to develop a rule that will cover all the contingencies and still be practical".

This underlines the need for incorporating fatigue mitigation strategies that are specific to the needs of an organization, in addition to any prescriptive rules that may be in place or may be added to future legislation.

3.3.2. Tactical Approaches

Companies may manage workplace fatigue using one or two tactical approaches – immediate or short-term initiatives with lower impacts than larger, strategic system or program approaches. While some of tactical approaches are standalone initiatives, others can be a part of an overall system or program approach.

Tactical approaches include, but are not limited to:

- Needs assessment and gap analysis (e.g. audit of fatigue risk management elements);
- Cost assessment of fatigue (e.g. the NSC "Cost of Sleep Deprivation" online tool);
- Surveys to identify fatigue issues;
- Education and awareness (e.g. alertness and healthy sleep);
- Training and skill development (e.g. recognizing signs and symptoms of fatigue, assessing risk, fatigue countermeasures);
- Work and shift scheduling (e.g. fatigue modelling, fatigue/alertness calculators, fatigue likelihood matrix/index, estimations of risk of injury and incidents associated with features of work schedules);

"While technology is promising for fatigue identification and monitoring, these devices and systems often require refinement and customization to be integrated into regular operations."

- Workload review of physical job demands;
- Workload review of cognitive job demands;
- Fit for duty assessments;
- Inclusion of fatigue in risk assessment methodologies (i.e. fatigue risk assessment);
- Fatigue reporting systems;
- Procedures to book off for rest/fatigue/fit for duty;
- Sleep apnea program or sleep disorder screening/ management;
- Napping or recovery procedures;
- Lodging evaluation (for sleep/napping/recovery) for environmental factors;
- Access and use of caffeine;
- Emergency response procedures;
- Investigating fatigue in incident investigations; and
- Technology implementation;
  - Biomathematical software for fatigue modelling;
  - Actigraphy and wearable monitors;
  - Eye-tracking (biofeedback) fatigue detection/ monitoring;
  - Psychomotor vigilance testing.

While technology is promising for fatigue identification and monitoring, these devices and systems often require refinement and customization to be integrated into regular operations. As for many personalized technological advancements, barriers to entry exist, including high costs and lack of scientific validation.

3.3.3. Strategic Approaches

Strategic approaches include larger, overall plans or programs that organizations adopt to manage workplace fatigue. These include frameworks such as an FRMS or fatigue risk management plans or programs.

3.3.3.1. Fatigue Risk Management Systems (FRMS)

A comprehensive summary of fatigue risk management in the workplace was developed in 2012 by the American College of Occupational and Environmental Medicine's Task Force on Fatigue Risk Management [19]. The summary provides information to assist occupational and environmental medicine physicians in promoting and supporting the development and implementation of an FRMS. Key aspects covered by the document include:

- the risk of employee fatigue;
- the history and limitations of duty-rest regulations;
- emergence of FRMS as the international standard for mitigating fatigue risk;
- building support for an FRMS;
- designing an FRMS;
- establishing continuous improvement; and
- identifying, collecting, and analyzing metrics.

FRMS is a safety management system (SMS) approach with clearly established elements [19]. They include:

1. A fatigue management policy;
2. Fatigue risk management, including collecting information on fatigue as a hazard, analyzing its risk, and instigating controls to mitigate that risk;
3. A fatigue reporting system for employees;
4. Fatigue incident investigation;
5. Fatigue management training and education for employees, management (and families);
6. Sleep disorder management; and
7. Internal and external auditing processes for the FRMS that deliver corrective actions through a continuous improvement process.

With the exception of sleep disorder management, which is specific to fatigue, Lerman et al. [19] noted that the elements listed are the same as would be found in most SMS. In that regard, the FRMS could be integrated as part of an existing SMS by reviewing each element through a fatigue lens. Whether integrated or not, an effective FRMS approach must be scalable.

In Canada, only the aviation sector has adopted an FRMS as a strategic approach to managing workplace fatigue. New regulatory requirements for the management of flight crew fatigue were published in the Canada Gazette II in 2018 [15]. This amendment of the Canadian Aviation Regulations (CAR) introduced FRMS as an alternative approach to the prescriptive flight, duty and rest requirements for managing flight crew fatigue. The components of an aviation FRMS are described in Table 6 [111].

Accordingly, the Civil Aviation Safety Authority (CASA) states that, "a fatigue risk management system is designed to create a flexible operating environment in which potential fatigue-related risks can be highlighted and managed" [112].

Dawson and McCulloch [113] established a conceptual framework for fatigue management that considers four levels of error trajectory prior to any actual fatigue-related incident (see Figure 1). It follows a SMS approach in that it includes a fatigue hazard identification process with subsequent control mechanisms. At each point along the causal chain of events, there is an opportunity to implement hazard assessment activities and corresponding control mechanisms. The hazard

Table 6 – *Components of Fatigue Risk Management Systems*

(Adapted from Federal Aviation Administration Advisory Circular 120-103A Table 2-1) [111]

Components	Elements
FRMS policy and documentation	▪ A fatigue risk management policy ▪ FRMS documentation
FRM	▪ Identification of hazards processes ▪ Risk assessment ▪ Risk mitigation
Safety assurance (SA) processes	▪ FRMS performance monitoring ▪ Management of operational & organizational change ▪ Continuous FRMS improvement
FRMS promotion processes	▪ Identification of hazards processes ▪ Risk assessment ▪ Risk mitigation

assessment levels consider if there are sufficient sleep opportunities, sufficient sleep obtained, fatigue-related behaviours, fatigue-related errors, and learnings from incidents.

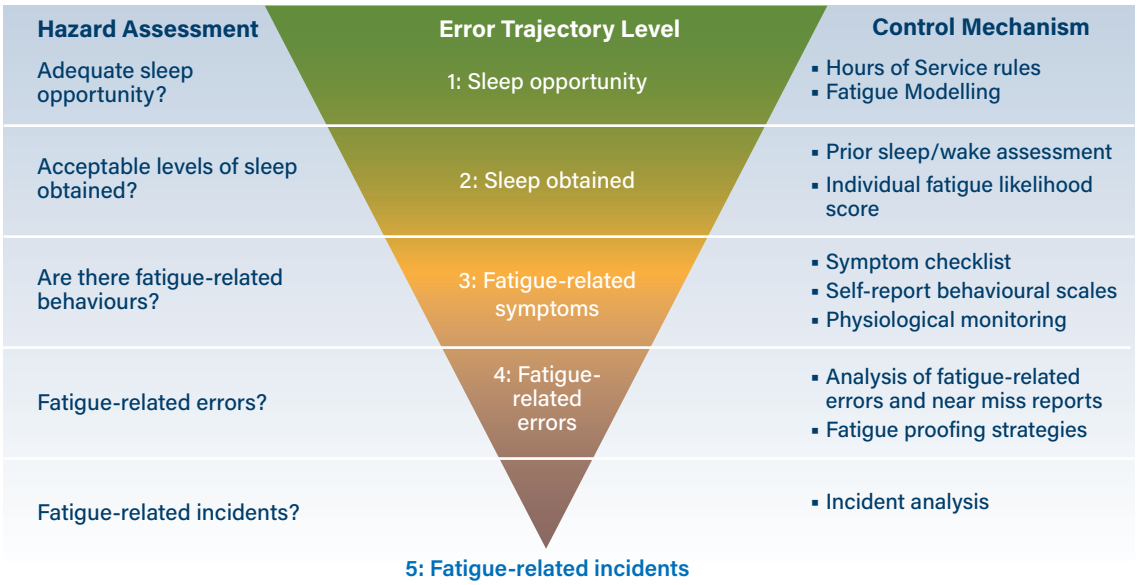
One of the key components of an FRMS is the shared responsibility between the organization and the employees. The organization must arrange work schedules that provide enough opportunities for rest, training to support fatigue management, and procedures for monitoring and managing fatigue within the organization. The employee is responsible for managing their free time to be rested and fit for duty, to attend training and implement recommendations, and to report cases of fatigue so that they can be better avoided in the future [19].

Research into the effectiveness of an FRMS approach has identified key concepts for success, including that it be evidence-based, data driven, cooperative, fully implemented (system-wide), integrated (into safety management), continuously improved, budgeted and owned (by senior leadership) [19].

3.3.3.2 Fatigue Risk Management Programs and Plans

Rather than an FRMS, companies sometimes adopt a "program" or "plan" that includes multiple tactics to address fatigue-related risk. A program may have some elements and components of an FRMS. The North American Fatigue Management Program (NAFMP), for example, places emphasis on specific components such as training and sleep disorder screening [16]. Rail fatigue management plans include specific considerations related to education and training, scheduling practices, dealing with emergencies, alertness strategies, rest environments, implementation policies, and evaluation of fatigue management plans and crew management effectiveness. The marine FMP consists of an implementation plan, training module, and guidelines for scheduling pilots and for monitoring and evaluating the FMP [62].

Figure 1 – *Defences in Depth Approach to Fatigue Management (Adapted from Dawson & McCulloch, 2005)* [113]



"Existing standards could be leveraged to establish ways to identify fatigue, assess the risk, develop control measures, and review/monitor the risks."

For pipelines in Canada, the FMP requirements include, at minimum,

- Roles and responsibilities in fatigue management;
- Hours-of-work rules and limitations;
- Processes for self-identification of fatigue and identification of fatigue in coworkers or subordinates;
- Processes for identification and management of workers with conditions that increase susceptibility to fatigue;
- Resources available for fatigue management and support, including locations and rules for napping, if permitted;
- Training related to fatigue awareness and management; and
- Processes for problem identification, trending, and resolution [70].

For the Canadian upstream oil and gas industry, their guidance identifies components necessary in a fatigue risk management program [10]. A unique aspect is the incorporation of a decision tree to help companies identify and scale their program needs based on the nature of work and level of risk. Low-risk organizations that operate in controlled environments with no outside risks may not require fatigue controls other than general awareness on fatigue risk management. High-risk organizations that operate vehicles or have safety critical processes with the potential for significant failure consequences may need to develop and implement a full FRMP. The program includes safe work practices to recognize symptoms, assess contributing factors, investigate incidents, and develop countermeasures.

3.3.4. Summary of Approaches for Managing Workplace Fatigue

Given the range of approaches applied for managing workplace fatigue – from prescriptive rules to strategic, large-scale programs, Canadian guidance for selecting an approach based on company size and resources would be beneficial. A decision aid could be considered to assist in determining the scale of program needed given the nature of work and level of risk.

Existing standards could be leveraged to establish ways to identify fatigue, assess the risk, develop control measures, and review/monitor the risks. This includes building upon existing risk assessment approaches, both international (ISO 31000, *Risk Management*) [109] and Canadian (CSA Z1002, *Hazard Identification and Elimination and Risk Assessment and Control*) [114]. Guidance needs to be provided on a risk assessment process that includes hazard ID, risk assessment, and implementation and evaluation of controls.

3.4. Education and Training

Providing education and training to employees, supervisors and leadership/management is often one of the first initiatives taken by companies, partly due to provincial and federal legislation that mandate a set number of hours for training in health and safety. Education is necessary to impart knowledge about the

impact of fatigue and to foster the awareness needed for organizational change in integrating fatigue risk management. Training is required to provide the skills needed to identify hazards, control risk, and develop and implement an FRMS.

Employee fatigue training and sleep disorder management have been identified as a key level of defence against errors from fatigue [115]. Fatigue risk management training has been shown to positively impact both knowledge and behaviour [116]. Lerman et al. [19] indicated the need for fatigue management training and education at all levels within the organization, with the inclusion of family members.

Lerman et al. [19] describe principles that should be included in education programs for employees:

- Hazards of working while fatigued and the benefits of being well rested;
- Impact of chronic fatigue on personal relationships, mental/physical well-being, as well as general life satisfaction;
- Recognizing that although fatigue cannot be eliminated, it can be managed and minimized;
- Adequate quantity and quality of sleep is key to managing fatigue;
- Basics of sleep physiology, circadian rhythms, and what is getting adequate sleep;
- Sleep hygiene — how to obtain adequate quantity and quality of sleep;
- Sleep disorders — why they matter, how to tell if one may have one, and what to do about it;
- Importance of diet, exercise, stress management, and management of other health conditions that affect fatigue, as well as information about how to address these issues;
- How to recognize fatigue in oneself or one's coworkers;
- Alertness strategies to be used while at work such as appropriate use of caffeine, rest or exercise breaks, and social interactions; and
- Advice on managing personal relationships for shift workers.

Supervisors also require additional training that includes [19]:

- How to implement the company's approach to shift scheduling, including any guidance for determining when and how deviations can be implemented; and
- How to recognize fatigue and what can be done to mitigate or manage it in both the short-term and when/if it seems to be chronic.

3.4.1. Education and Training Approaches

An environmental scan was completed to review education programs and training frameworks currently being used by Canadian workplaces to address fatigue. Industry sectors primarily utilize industry-related guidance documents to develop training content. Some industries have developed detailed guidance on education and training approaches, and have developed materials (e.g. presentations, workbooks, online courses) that contain pre-populated content. Five education and training approaches were reviewed, including:

- Transport Canada's FRMS for Canadian Aviation Toolbox [55];
- Transport Canada's Fatigue Management Program for Canadian Marine Pilots [39, 62];
- North American Motor Transport Association's NAFMP [16];
- Canadian Nuclear Safety Commission's (CNSC) Managing Worker Fatigue [40]; and
- BC Municipality Safety Association's Fatigue Management Courses.

These Canadian government and industry associations were selected because of their detailed approaches to the delivery of education and training across all levels of an organization.

3.4.1.1. Transport Canada's FRMS for Canadian Aviation Toolbox

Since 2007, Transport Canada has provided a *Fatigue Risk Management System for the Canadian Aviation Industry – FRMS Toolbox* on their website [55]. A variety of materials are provided that are targeted to

employees, trainers and managers. A workbook and a PowerPoint presentation are provided along with a trainer's handbook. The materials include content on fatigue, fatigue management systems, and individual fatigue management strategies.

The trainer's handbook includes background information for the delivery of a workshop, learning outcomes, and questions frequently asked by participants. The handbook does not identify trainer requirements, as it is targeted to organizations with an in-house safety training program with trainers already present. An employee training assessment section is provided as an optional module to assess employee competence of the topics covered. A questionnaire is also provided to determine whether employees understand the material presented.

Chapter 4 of the toolkit addresses training and education as part of the FRMS. The chapter outlines details related to determining training needs based on the level of existing knowledge, the level of fatigue-related risk, and the requirement of training resources. The guidance on fatigue management education and training underlines the importance of competency-based training techniques and assessments, as well as refresher courses. Chapter 4 also provides guidance on the training environment and the expected outcomes.

3.4.1.2. Transport Canada's Fatigue Management Program for Canadian Marine Pilots

The World Maritime University [117] declared that, "fatigue is widely accepted as an unavoidable condition within the marine industry and is recognized as a contributing factor in many marine accidents". To improve awareness of the factors that contribute to fatigue, the TSB recommended that, "the Department of Transport and the Canadian pilotage authorities develop and implement an awareness program to provide guidance to operational employees, including pilots, on reducing the adverse effects of fatigue on job performance" (TSB Recommendation M99-04). In response to this recommendation, an FMP was developed for Transport Canada [62]. Development of the program involved research into fatigue issues in marine pilotage and program development based on three components:

1. An implementation plan;
2. A training module; and
3. Guidance for scheduling pilots and for monitoring and evaluating the FMP.

The F*atigue Management Guide for Canadian Marine Pilots: A Trainer's Handbook* [39] is the primary reference tool for the trainer responsible for the marine pilot fatigue management training module. *The Fatigue Management Guide for Canadian Marine Pilots* was developed for participants in the six-hour training workshop. The content of the guide includes sleep fundamentals, biological clock, effects of irregular work shifts, and coping strategies at home, work and driving.

Background material and supporting research is provided in a companion publication [118].

3.4.1.3. North American Motor Transport Association's North American Fatigue Management Program (NAFMP)

In 2013, NAFMP [16] was launched as a tool for commercial truck and bus carriers and their employees to help identify and manage fatigue and fatigue-related issues to improve driver and public safety. It consists of three instructional methods (instructor-led PowerPoint presentations, web-based non-interactive courses, and web-based interactive courses) to reach the widest audience possible. The NAFMP comprises 10 training and educational modules that target carrier executives and management personnel, drivers, drivers' families, shippers and receivers, and dispatchers. These modules incorporate background information about fatigue, causes and characteristics of fatigue, and strategies for the various audiences to reduce commercial motor vehicle (CMV) driver fatigue. The content was developed by the Virginia Tech Transportation Institute. Module exams are provided for six of the 10 modules and allow drivers to earn FMP certification.

The NAFMP [16] includes guidance on the important characteristics to consider when choosing trainers to lead FMP instruction, stating that trainers must, "effectively provide trainees with fatigue management knowledge, skills and abilities, so it is critical for

these instructors to be carefully selected and trained in strategies designed to provide the most effective instruction possible". Although many prerequisites and considerations are provided, there is no requirement for fatigue management knowledge or expertise beyond the material presented in the FMP. The implementation manual offers guidance on providing FMP education and training as a step in developing, implementing and evaluating the FMP.

3.4.1.4. Canadian Nuclear Safety Commission's Managing Worker Fatigue

In 2017, the CNSC issued regulations (REGDOC-2.2.4, *Fitness for Duty: Managing Worker Fatigue*) that stipulate required training for all individuals involved in managing worker fatigue within an organization [40]. Part 3.4 includes guidance on the specific topics that must be addressed and establishes foundational or minimal requirements for fatigue-related training. Part 3.4 states that training and education about fatigue and measures for managing risks associated with worker fatigue should address the following topics:

- Causes, risks and consequences of fatigue (e.g., effects of fatigue and circadian rhythms on alertness and performance; importance of sleep and strategies to maximize the benefits of recovery opportunities; sleep disorders and their treatment; symptoms of fatigue; measures to minimize the effects of fatigue; commuting);
- Measures for managing worker fatigue (e.g., authorities, accountabilities and responsibilities for managing worker fatigue and controlling hours of work; process to follow when a performance impairment due to fatigue is suspected); and
- Regulatory requirements related to fatigue and hours of work.

Requirements and guidance for training systems are found in REGDOC-2.2.2, *Personnel Training* [11]. The CNSC does not provide the specific content of the training, leaving licensees to find qualified personnel to develop and implement the training system that can address the required topics. The documented qualification requirements for trainers, particularly in the areas of subject matter expertise and instructional skills, are not stipulated.

3.4.1.5. British Columbia Municipal Safety Association's Fatigue Management Courses

In 2018, the British Columbia Municipal Safety Association (BCMSA) responded to requests from its membership, as well as the drive by WorkSafe BC for organizations to start identifying and managing fatigue-related risk by investigating education and training options. They subsequently offered two training initiatives: one for supervisors and safety & health committees and one for leadership/management. While some content is consistent for all audiences (e.g. understanding fatigue, the science of sleep), separate training initiatives have been delineated, reflecting the need to tailor the content to different audiences (https://www.bcmsa.ca/what-we-do/training/).

3.4.2. Comparative Analysis of Training and Education Programs

A comparison of the five Canadian training and education programs is provided in Table 10. These programs were selected due to their broad reach and their detailed outline of approach to the delivery of education and training across all levels of the organization. Common elements exist across all five agencies with respect to fatigue risk management education and training. For example, all agree that content should be customized for various roles/responsibilities (e.g. employees, supervisors and leadership). Employee training, for example, should focus on sleep hygiene strategies and incorporate materials that can be shared with the family. Supervisor training should focus on recognizing and assessing fatigue-related risk and developing controls.

This would include tactical applications for fatigue risk assessment. Leadership/executive training should focus on a systems approach to managing fatigue-related risk. The education and training specific to leadership may be required to help obtain the buy-in required for approval of fatigue risk management initiatives. It should include guidance on policy development, and include evidence required for a business case related to health and wellness, performance efficiency, and safety management.

	Transport Canada – Aviation [55]	Transport Canada – Marine [39,62]	North American Fatigue Management Program [16]	Canadian Nuclear Safety Commission [40]	BC Municipality Safety Association
Target Audiences	Employees, trainers, managers.	Marine pilots and trainees.	Carrier executives and management personnel, drivers, drivers' families, shippers and receivers, and dispatchers.	Those with authorities, accountabilities, and responsibilities for managing worker fatigue.	Supervisors and safety & health committees; leadership and management. (Employee awareness training in development).
Methods and Materials	Workbook for employees; PowerPoint presentation; employee training assessment; fundamental knowledge questions questionnaire.	PowerPoint presentation; reference and guide for workshop participants; trainer's handbook.	PowerPoint presentation (with instructor notes); 10 modules with online courses (interactive or non-interactive); module exams; FMP certification.	No materials provided. Licensees to find qualified personnel to develop and implement training.	PowerPoint presentations; manuals; workbooks. Courses developed and led by external consultants.
Content	Includes content on understanding fatigue, individual strategies and FRMS.	Sleep fundamentals, biological clock, effects of irregular work shifts, and coping strategies at home, work and driving.	Includes causes and characteristics of fatigue and individual strategies, sleep disorder management, scheduling tools, and monitoring technologies. Content customized to target audience.	Provides guidance on topics. No content provided.	Content includes understanding fatigue, science of fatigue and sleep, lifestyle factors, FRMS, fatigue risk assessment, and developing a path forward. Content customized to target audience.
Requirements of Trainers	None. Assumes in-house trainers. Provides trainer handbook.	No qualifications requirements.	Train-the-trainer module. Suggests prerequisites for trainers.	No qualification requirements.	Selected external subject matter expert with instructional skills and applied experience.
Guidance on Training and Education (T&E) (for organization)	Chapter on T&E in a FRMS. Includes determining training needs, assessing compliance, training environments, and expected outcomes.	The FMP implementation plan includes T&E as a key element.	Implementation manual provides guidance on FMP education and training.	Requirements and guidance for training systems.	Content on FRMS includes T&E as a key element of FRMS.

"Some Canadian operations may impose special circumstances that contribute to fatigue-related risks in Canadian workplaces."

While acknowledging the necessity of addressing both employee and management strategies for mitigating risk, the method of delivery and amount of detail varies among programs. Transport Canada provides guidance material that can be delivered by in-house trainers regardless of expertise or experience, while the CNSC and BCMSA prefer that qualified individuals are relied upon, although they do not formally define what "qualified" refers to.

Except for the CNSC, all have prepared slide decks with instructor notes, trainer handbooks, and various tools to assess the competency gained and retained through training and education. Guidance on the integration of training and education within a strategic approach and recommended approaches to ensuring effective training initiatives have been incorporated in all five agencies. This includes aspects such as determining training needs, designing and developing training content, and assessing competence.

What is unknown is the quantity and quality of education and training that has taken place as a result of these provisions. The agencies listed in the comparative analysis, except for the BCMSA, do not record metrics relative to training completed, competencies, or outcomes. Further, while the availability of existing training guidance and materials is beneficial, individual companies must still choose to adopt and deploy the materials, modify the materials for their own use, or develop original materials that suit their purpose.

3.5. Canadian Workplace Considerations

Some Canadian operations may impose special circumstances that contribute to fatigue-related risks in Canadian workplaces. The literature review and environmental scan identified the following as potential risk factors for some Canadian operations:

- Remote working locations and/or long commutes, including fly-in/fly-out operations (FIFO);
- Remote lodging and sleeping away from home;
- An aging workforce;
- Work culture and vacation;
- Secondary jobs or volunteer workers; and
- Working north of the 60th parallel;

3.5.1. Remote Work Locations and/or Long Commutes

The geography of Canada and the distribution of the population lends itself to long distance travel to move workers, goods and services to and from worksites. FIFO is a common occurrence in the extractive industries sector and is used to move employees to and from a remote worksite. In 2008, Muller et al. conducted an epidemiological study of fatigue levels associated with FIFO operations at a mining site in Australia [119]. Rosters typically consist of many consecutive shifts followed by many days off (e.g. 2 weeks on, 2 weeks off). Over the course of a 28-day roster, results

indicated significant increases in fatigue at the finish of both night shifts as well as day shifts onwards after the 8th day assignment. The magnitude of the impact was noted to have performance-related safety implications greater than what would be expected with blood alcohol concentrations of 0.05%.

International guidance documents for the oil and gas industry have been developed with specific considerations on fatigue in FIFO operations [74]. These apply to Canada as well. Further, the Canadian Association of Petroleum Producers (CAPP) released a Code of Practice targeted on the Newfoundland and Labrador offshore petroleum industry. For remote offshore locations that do not allow for 24 hours of consecutive rest per week, the code outlines fatigue management principles to consider if an exemption is requested [69].

3.5.2. Remote Lodging and Sleeping Away from Home

As a result of the geographical locations of work, some industry sectors have relied on remote lodging or camps to house workers while on their shift rotations. There are few studies that consider all the extraneous and individual variables that can impact sleep both at home and away from home. A 2015 clinical review indicated that variables such as timing and duration of breaks, commute length, sleeping environment (noise, movement, vibration, light), circadian phase, demographic factors, familiarity with the sleep location, and the interaction of these variables need to be further investigated [120].

Sleeping away from home is a regular occurrence in long distance transport operations such as trucking, rail, aviation and marine, and often takes the form of sleeping in vehicles or vessels. Pilcher and Coplen [121] studied 198 locomotive engineers and their railway schedules. They revealed that the quantity of sleep obtained while at home in on-call conditions was inadequate and the engineers increased their reliance on recovery sleep when at terminals away from home. While more total sleep occurred at these away from home locations, the quality of sleep suffered significantly.

In March 2013, a study of Australian truck drivers utilized both subjective and objective measurements to compare quality and quantity of sleep obtained when at home versus in the berth of their truck. Subjectively, respondents indicated better quality and quantity of sleep when at home. Objectively, data reflected a trend toward longer sleep periods when at home, but no significant impact on the quality of sleep [122].

In the marine sector, sleeping on a vessel has been purported to have its own unique challenges, including noise, vibration and the number of occupants in shared sleeping facilities. Various studies have demonstrated a reduction in sleep quantity and quality in such circumstances, including passenger ferry crews [123] and commercial fishermen [124].

Rail FMPs stipulate requirements for rest environments [13]. For the motor carrier industry, the NAFMP includes guidance for sleep berth [16]. The International Maritime Organization (IMO) Guidelines on Fatigue provide specific details on lodging requirements relative to ensuring adequate sleep [63]. In aviation, guidance stipulates layover hotels should be carefully vetted to ensure that they provide excellent facilities for sleep, eating, and exercise [74].

3.5.3. Aging Workforce

In a review of the 2016 Census Poll conducted and analyzed by Statistics Canada, nearly one in five (19.8%) Canadians aged 65 and older reported working at some point in 2015, double the proportion in 1995 [125]. Deciding to work past a traditional retirement age may be by choice or out of necessity. Regardless of the reason why, science recognizes that as we age, the quality and quantity of our sleep is reduced even though the need for sleep remain constant throughout adulthood [126,127]. In 2011, a systematic review of 60 studies indicated that age is one of several individual factors that affect shift work tolerance and revealed that older workers have a reduced tolerance to shift work [128].

Guidance documents cite age as an "individual" or "worker" factor that will influence susceptibility to fatigue [56, 75, 110]. The Fatigue Management Guide for Canadian Marine Pilots: A Trainer's Handbook [39] includes details

on the impact of age on sleep and coping with irregular shifts. Key points are summarized below:

- Coping with irregular or erratic shifts becomes more difficult as we age with significant performance decrements noted by the age of 40. The International Labour Organization (ILO) has recommended restricting workers to day work if they are 55 or older, or if they have accumulated a significant number of years performing shift work activities (20 years or more).
- Sleep efficiency, which refers to how quickly we fall asleep and stay asleep, tends to drop as we get older. The result is shorter sleep periods and more awakenings. This coincides with changes in how much time is spent in each of the various stages of sleep, with older workers spending more time in REM sleep (good for cognitive repair) but less time in deep sleep (necessary for physical repair). Napping is a suggested strategy for Marine Pilots over the age of 45 to help offset the sleep challenges they face.

The older we get, the more likely our rhythms will shift us towards being a "morning lark", with a preference to rising early in the morning. Older workers who are on evening or night shifts will have more difficulty staying awake when working these schedules and may be diagnosed with advanced sleep phase syndrome.

3.5.4. Work Culture and Vacation

In the context of this report, work culture is not to be confused with organizational culture. Work culture reflects an individual's propensity for working versus taking time off or away from work. It may be influenced by the organizational culture that is present.

Compared to other advanced economies, including the European Union member countries, only Japan and the United States have fewer total paid vacation and paid holidays than Canada. Canada mandates a two-week statutory minimum annual leave and nine paid holidays. In 2014, a survey conducted for TD Canada Trust [1292] discovered that less than half of Canadian workers use all their paid days off. A Randstad survey in 2015 [130] revealed that 40% of Canadians didn't mind working while on vacation. An ADP Canada Sentiment Survey [131] revealed that less than half of those who are provided with four weeks annual vacation will use all of it (48.5%), with 5% admitting to omitting vacation entirely.

Company cultures in Canada reward performance that accompanies long work hours and/or availability beyond normal working hours. However, research suggests that working more hours does not equate to working more efficiently. According to statistics released in 2015, the Organisation for Economic Co-operation and Development (OECD) has noted that France leads with an average of 30 vacation days a year, while Canada devotes the least amount of time to leisure activities. However, France has a more efficient workforce producing approximately $63 (US) worth of national GDP per capita per hour, compared to Canada who produce about $51 per hour worked [132].

Most guidance documents on workload focus on maximum HoS guidelines and do not specifically reference vacation time as a fatigue countermeasure. Using vacation time to rest and recover is a "shared responsibility" where companies must provide sleep opportunities and time off from work, and employees must use the time provided to rest and recover.

3.5.5. Secondary Jobs and/or Volunteer Work

Statistics Canada revealed that, "the period from 2005 to 2015 saw an overall shift from full-time, full-year employment to part-time or part-year work" [125]. With fewer full-time positions available, secondary jobs are becoming more commonplace to fill the income and benefits gap. There is limited research on the impact of secondary jobs on workplace fatigue. In a 2015 Australian review of volunteer firefighters, managing fatigue was difficult and/or politically untenable, as it is an essential service [4]. While they noted that the individuals themselves had informally adopted countermeasures, there was a lack of formal strategies in place. There was also evidence that the workers would not report the effects of fatigue, reflecting the "indefatigability" they are supposed to demonstrate, perhaps at the expense of safety in a high-risk scenario.

Guidance documents address secondary jobs primarily through an emphasis on the principle of "employee responsibility", where it is the employee's duty to take time off (i.e. sleep opportunity) to adequately rest and

recover. For example, Safe Work Australia [93] states that, "Workers must take reasonable care for their own health and safety and must not adversely affect the health and safety of other persons. Workers must also comply with any reasonable instruction and cooperate with any reasonable policy or procedure relating to fatigue at the workplace, such as policies on fitness for work or second jobs." In New York, the New York City Transit Authority (NYCT) Rapid Transit Operations Division does not allow part-time positions and all employees must obtain permission to hold a second job [133].

In Transit operations where split schedules are common, there is much debate surrounding the length of the split and its impact. The Transportation Research Board acknowledges that the employer has a responsibility to evaluate the design of split schedules for fatigue factors [133]. Fatigue researchers indicate that by allowing a larger block of time off between the split (such as three hours) it will accommodate a nap or rest opportunity for the worker [134, 135]. Conversely, concern has been expressed that if the split is too large, it accommodates for workers to take on second jobs [136].

3.5.6. Work North of the 60th Parallel/Light Exposure

Work north of the 60th parallel is not only remote with unpredictable weather, but it also submits workers to days that can have extended or short exposures to daylight. Little research has examined how climate and latitudinal factors can affect the human chronotype — a person's propensity to sleep at a particular time during a 24-hour period. In northern Russia, it was noted that chronotypes were skewed more to being "night owls" than "morning larks" compared to central Europeans, and the further north the latitude, the more pronounced were these effects [137]. This was noted to cause greater circadian desynchronization and has been subsequently used to explain elevated risks for age-specific diseases in these locations. A study in Norway [138] demonstrated a similar sleep-wake phase delay. The results indicate that while sleep is longer when exposed to more darkness, there are health consequences, likely associated with the lack of sufficient light exposure. Findings related to an increase in sleep disturbances and depression have been replicated in several other studies conducted in northern latitudes [139-142].

There was a lack of research on the impact of limited or extended light on those individuals who are not residents of these latitudes, such as workers who routinely commute between central and northern latitudes (e.g. FIFO operations).

3.5.7. Discussion on Canadian Considerations for Workplace Fatigue

Only remote working locations (i.e. FIFO) and remote lodgings (including sleeping away from home) had supporting research and detailed guidance to support fatigue risk management efforts. These aspects should be recognized as potential factors to consider and address in the overall approach to managing fatigue, as well as in training and education segments.

Guidance documents list age as a factor to consider when identifying fatigue-related hazards. However, there is minimal guidance on the control measures appropriate to address fatigue-related risks associated with aging.

The other aspects of some Canadian operations (i.e. work culture, secondary jobs, working in the high North, and temporary/seasonal jobs) did not have supporting research directly linking to workplace fatigue. The guidance related to these aspects focuses on key principles of a FRMS and the need for "shared responsibility" for both employees and employers. These aspects require further investigation to validate their inclusion in guidance documentation.

4 Conclusions

This report synthesizes the available evidence from the literature and an environmental scan to define workplace fatigue and identify existing national and international legislation and best practices related to workplace fatigue.

The definition of fatigue varied depending on the type of industry and associated tasks. However, there were causal factors (physical, mental and sleep), states of fatigue (physical and mental) and effects on performance (physical and mental) that were common to a majority of the definitions used in Canada. Terminology has been

Table 11 – *Summary of Research and Guidance Related to Workplace Considerations*

Canadian Workplace Considerations	Related Research	Related Guidance
Remote working locations and/or long commutes, including FIFO ops.	Increased fatigue after 8th shift on 28-day rosters (mining).	CAPP Code of Practice Energy Institute FIFO.
Remote lodging and sleeping away from home	▪ Several variables can impact fatigue. ▪ Inadequate quantity of sleep at home in on-call condition. Poor quality of sleep away from home (rail). ▪ Longer sleep periods obtained at home, but no significant impact on quality of sleep compared to berth of truck (trucking). ▪ Reduced sleep quality and quantity sleeping on a vessel (marine).	▪ Rail FMPs stipulate requirements for rest environments. ▪ NAFMP includes guidance for sleep berths. ▪ IMO Fatigue Guidelines provide specific details on lodging requirements relative to ensuring adequate sleep. ▪ IATA/ICAO/IFALPA (aviation) stipulates layover hotel must be carefully vetted to ensure that it provides excellent facilities for sleep, eating, and exercise.
Aging workforce	▪ There is an increase in the proportion of Canadians aged 65 and older who are working. ▪ Research supports that older workers have increased risk of fatigue due to reduced sleep quality and quantity. ▪ Age degrades ability to cope with irregular schedules.	Guidance lists age as a variable impacting fatigue-related risk, but does not provide specific guidance on age-related controls.
Work culture and vacation	▪ Less than half of Canadian workers use all their paid days off. ▪ 40% of Canadians did not mind working while on vacation. ▪ Working more hours does not equate to working more efficiently. ▪ No research on the impact of Canadian work culture/vacation on workplace fatigue.	Guidance promotes a shared responsibility to use vacation to rest.
Secondary jobs and/or volunteer workers	▪ Work is shifting from full-time to part-time, and secondary jobs are becoming more common. ▪ No research on the impact of secondary jobs on workplace fatigue.	Guidance promotes employee responsibility to be rested for work.
Work north of the 60th parallel	Health consequences associated with lack of sufficient light exposure. No research related to temporary work in northern latitudes.	No guidance.
Abbreviations:	**CAPP** Canadian Association of Petroleum Producers **FIFO** Fly-in, Fly-out **FMP** Fatigue Management Plan **IATA** International Air Transport Association	**ICAO** International Civil Aviation Organization **IFALPA** International Federation of Air Line Pilots' Association **IMO** International Maritime Organization **NAFMP** North American Fatigue Management Program

"Combining a risk-based approach that complements regulations can offer more flexibility to individual organizational needs and unique operational challenges."

provided for consideration as a foundational definition for fatigue. A global definition, spanning several industries, may want to address all the aspects to demonstrate the complexity and multidimensional construct of fatigue.

In Canada, there is a wide variety of legislation, industry standards and guidance that address workplace fatigue. The transportation and nuclear sectors have led the way in terms of both regulations and fatigue risk management plans and programs. Even so, there has been very little formal evaluation of the effectiveness of these efforts. Additionally, guidance on workplace factors contributing to fatigue is limited when stepping outside of these industries. Two aspects, remote working locations (i.e. FIFO) and remote lodgings (including sleeping away from home) were supported by research, suggesting these conditions should be recognized as potential factors to consider and address in the overall approach to managing fatigue, as well as the training and education segments.

There is considerable variance in the approaches taken by organizations to address workplace fatigue. Many strategies to address workplace fatigue are isolated to the needs of a specific industry. Some industry sectors have no industry-specific guidance on fatigue risk management. In lieu of regulations, some provincial and national OHS agencies have provided bulletins, educational materials and generic information to drive awareness of fatigue in the work environment. However, few have outlined a process for developing and implementing a fatigue risk management program based on risk assessment within a management system.

Internationally, there have been many initiatives to address the potential risks related to workplace fatigue. Early attempts to manage fatigue came primarily through the implementation of HoS legislation. However, prescriptive rules do not address the range of operational contingencies across multiple industries. Fatigue science and evidenced-based best practices have evolved to reveal new opportunities for managing the complexities of workplace fatigue. Combining a risk-based approach that complements regulations can offer more flexibility to individual organizational needs and unique operational challenges. Concepts such as an FRMS, or a FMP that is scaled to meet the specific needs of an organization, are also gaining support. These international efforts have been increasingly adopted into Canadian efforts to address workplace fatigue.

The development of a national standard or standards-based solution may help to address gaps in the existing legislation, industry standards and guidance documents. A standard could:

1. Provide a common definition of workplace fatigue that can span several industries;
2. Outline the strategic approaches for fatigue risk management that can be scaled to meet the needs of organizations with various resources;

3. Identify tactical approaches that may be considered to assess fatigue. This should include procedures and tools to address fatigue as a hazard that is assessed and controlled as part of a hazard identification and risk assessment process;
4. Foster engagement and assist in securing buy-in to address fatigue-related risks, especially in companies without existing regulations;
5. Foster education and training by directing organizations to minimal requirements currently established for fatigue risk management content; and
6. Support efforts to manage workplace fatigue by directing organizations to existing guidance documents.

Rather than develop a new, stand-alone standard, consideration could be given to revising existing standards that relate to workplace fatigue. Fatigue can be discussed in the context of human factors, ergonomics, and OHS. For example, the CSA Express Document, CSA EXP248-15, *Pipeline human factors,* includes a clause (13) that addresses fatigue management [70]. As well, fatigue may be discussed as part of "Fit for Duty" along with drugs and alcohol, mental health, and physical health/fitness. Workplace impairment standards might address fatigue along with other types of impairments such as stress or drugs. CSA Group standards around psychological health and safety in the workplace [143] could also include aspects of fatigue, especially those related to psychological demands. A risk management standard (such as ISO 31000 [109] or CAN/CSA-Z1002-12, *Occupational health and safety – Hazard identification and elimination and risk assessment and control* [114]) could provide the basis for a risk-based approach to fatigue, addressing fatigue as a specific type of occupational hazard. The review indicates that procedures could be further developed to address fatigue as a hazard that is assessed and controlled as part of a hazard identification and risk assessment process. A risk-based approach essentially tailors the management process to the context within which the risk manifests. Existing Canadian OHS and risk management standards could be leveraged to establish ways to identify fatigue, assess the risk, develop control measures, and review/monitor the risks.

Canadian industry sectors and organizations in the early phases of fatigue risk management are faced with challenges associated with raising awareness of the topic, and securing the necessary buy-in. Minimal requirements for training and education have been established for some industries, along with educational content. However, this has yet to reach all industries and there is a gap in making stakeholders aware of the existing materials.

In some industry sectors, there are no guidance materials that have been customized to their terminology, tasks and culture. Thankfully, because much of the sleep and fatigue science applies for all humans, regardless of industry, there is an opportunity to leverage content that has been developed for other industries. This suggests a need for guidance that would outline the key content fundamental to understanding and addressing fatigue at all organizational levels.

The issues and gaps identified in this report reinforce the complexity of the topic of workplace fatigue. Development of a national standard or standards-based solution will require a process that recognizes the ongoing fatigue science research, learns from ongoing efforts, and engages multiple workplace stakeholders and perspectives.

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APPENDIX A - Summary of Legislation, Best Practices and Guidance on Workplace Fatigue

A.1 Summary of FRM Guidance for Key Industries/Sectors

Motor Carriers

In Canada, the motor carrier industry is governed by the *Federal Commercial Vehicle Drivers Hours of Service Regulations* (SOR/2005-313) [51] and the Motor Vehicle Transport Act [52]. Attempts to manage fatigue have focused primarily on prescriptive HoS regulations.

In Australia, the national legislation changed in 2014 to facilitate a single regulation for trucks over 4.5 tons. With the *Heavy Vehicle National Law* (HVNL), the responsibility for fatigue management has been moved from regional to national authority. The HVNL addresses prescribed work and rest schedules, vehicle standards, maximum permissible mass and dimensions and restraining of loads on heavy vehicles [53]. Fatigue is monitored by officials through required driver work diaries for previous shifts worked as recorded in a logbook. Fatigue management is managed nationally through an Advanced Fatigue Management policy that applies a Risk Classification System (RCS) to drivers based on drive/rest profiles. All drivers are required to complete a standard RSC matrix to evaluate their schedules and assign countermeasures for any risks noted. High-risk schedules are identified through analysis of the work and rest times.

Legislation in New Zealand includes "chain of responsibility" offences, a concept that is starting to appear in regulations [33]. These offences may apply to employers who knew, or should have known, that their drivers breached HoS limits. In the Australian federal trucking regulations, the chain of responsibility extends accident investigation and culpability to also consider latent organizational errors in addition to the active errors made by individuals.

Prescriptive HoS regulations in the motor carrier industry are limited in that they do not acknowledge potential conflicts when trying to accommodate for complex operational requirements (including unplanned events), collective agreements that provide incentives/disincentives to when employees choose to work, and employees' own personal preferences as dictated by lifestyle and potential earnings.

Aviation

New *Canadian Aviation Regulations* (CARs), published by Transport Canada allow pilots to fly up to 1000 hours a year, with tighter restrictions on how long pilots can work on any given day [54]. The rules also provide airlines with the alternative of setting up a FRMS that identifies the risk of pilots working extended hours, as well as measures to mitigate those risks. Since 2007, Transport Canada has also provided online access to a FRMS toolkit with guidance information and educational materials [55].

The European Aviation Safety Agency released a "Notice of Proposed Amendment" in 2009 that required all commercial air operators to have an FRMS in place by mid-2012. Operators can use an FRMS as part of a safety case to apply for an exemption from existing flight time limitations.

In the USA, prompted by National Transportation Safety Board (NTSB), the Airline Safety and Federal Aviation Administration (FAA) Extension Act of 2010 required airlines to develop a fatigue risk management plan by Oct 31, 2010.

In November 2011, the International Civil Aviation Organization (ICAO) released an amendment to Annex 6, Operation of Aircraft, Part 1, Section 4, Flight Operations and Appendix 8, FRMS Requirements. The amendment introduced a science-based approach to flight and duty time limitations (FTLs) and provided a

framework for regulators to oversee an FRMS. Prior to this amendment, the only international standards available for managing fatigue in flight operations were related to prescriptive FTLs. The traditional regulatory approach for managing crewmember fatigue has been to prescribe limits on maximum flight and duty hours and required minimum breaks within and between duty periods. It is a one-size-fits-all approach that does not consider operational differences. FRMS is an enhancement to FTLs, enabling an operator to customize FTLs to better manage fatigue-related risk to the operation.

In 2011, ICAO, the International Air Transport Association (IATA) and the International Federation of Air Line Pilots' Associations (IFALPA) released an *FRMS Implementation Guide for Operators* and ICAO released an *FRMS Manual for Regulators*, which provide detailed information for operators and regulators on implementing FRMS. They have since created a suite of fatigue management manuals directed to specific aviation service providers in different sectors of the industry (e.g. general aviation operators of large and turbojet airplanes; air traffic service providers) [56].

In 2014, the European Union Aviation Safety Agency (EASA) made amendments to their previous regulations to include a requirement for an SMS and FRM in every European airline by February 2016 [57]. The intent was to shift toward a performance-based environment with measurable safety outcomes. A general framework of guidance was provided to grant flexibility to operators. European National Aviation Authorities vary in their progress, with the UK Civil Aviation Authority at the forefront of FRMS implementation.

Other countries, such as South America and South East Asia, have also made strong progress in fatigue management ahead of other countries.

Rail

In Canada, fatigue management for rail has been governed by the *Work/Rest Rules for Railway Operating Employees* pursuant to section 20(1) of the *Railway Safety Act* 1985, which defines the requirements for hours of work and rest [58]. The rules include maximum duty time and mandatory off-duty times for railway employees. In 2006, The Minister of Transport, Infrastructure and Communities initiated the *Railway Safety Act* Review and an Advisory Panel made several recommendations. With respect to fatigue management, the Panel's final report made Recommendation #43 [13], as follows:

- "Fatigue management is dealt with in complementary ways, such as work/rest rules, fatigue management plans, and terms and conditions of employment.
- The current work/rest rules do not provide a satisfactory baseline framework for managing the risks associated with fatigue in railway operations. The rules should be amended to reflect current science on fatigue management.
- A robust system of fatigue management plans is needed. Transport Canada should audit them as it does for SMS plans.
- Fatigue management is also an issue that railways and employees should address in the establishment of terms and conditions of employment."

To address this recommendation, a Transport Canada document, "Fatigue Management Plans: Requirements and Assessment Guidelines", was produced by a working group and incorporated as a regulatory requirement into the Work/Rest Rules for *Railway Operating Employees* [58].

Amendments to Canada's *Railway Safety Management System Regulations*, 2015 required federal railway companies to develop and implement a safety management system, create an index of all required processes, keep records, notify the Minister of proposed changes to their operations, and file SMS documentation with the Department of Transport, when requested [144]. Efforts to expand fatigue risk management efforts included the integration of fatigue science principles into the SMS, but it did not include a formal FRMS. Section 28(1) of the *Railway Safety Management System Regulations* addresses a process with respect to scheduling:

> "a railway company must apply the principles of fatigue science when scheduling the work of the employees referred to in subsection (2), including the principles (a) that human fatigue is governed by physiology; (b) that human alertness is affected by circadian rhythms; (c) that human performance degrades in relation to hours of wakefulness and accumulated sleep debt; and (d) that humans have baseline minimum physiological sleep needs."

In April of 2017, Canada's Minister of Transport launched a two year Statutory Review of the *Railway Safety Act.* The review included an evaluation of the effectiveness of the current federal rail safety legislative and regulatory framework, the operations of the Act itself, and the degree to which it ensures rail safety [145].

Recommendation 3 specifically addressed fatigue:

> Recommendation 3 – "It is recommended that Transport Canada assume a leadership role on fatigue in the rail sector in order to set a flexible way forward that is in place in a timely fashion and includes:
>
> > A. working with employee representatives (unions), industry, and fatigue science specialists to develop a national approach to fatigue in the rail sector, including sustained collaboration between unions and industry; and
> >
> > B. regulating prescriptive minimum criteria (that reduce the current number of on-duty hours and provide increased opportunities for rest) and non-prescriptive measures based on evolving fatigue science."

Transport Canada is also currently conducting research to identify rail tasks with the greatest fatigue-related risk. The labour side in rail has established a website for reporting fatigue-related issues. As well, they are supporting independent studies to quantify the levels of fatigue experienced by rail workers.

Available for Canadians, the Railroaders' "Guide to Healthy Sleep" is a website [60] owned and funded by the Federal Railroad Administration that provides tools, tips and information to help railroaders—as well as families and friends—explore and improve sleep and find a healthy balance in life. It includes an "Anonymous Sleep Disorders Screening Tool" to help individuals assess their own sleep health.

Internationally, there has been a general move towards risk-based frameworks. In Australia, risk-based approaches to safety regulation were used since the Robens report [146] first articulated the benefits of performance-based regulatory models [147]. Australia's WHS laws were amended and have incorporated risk-based approaches since the 1980's. In 2006, the Australian Government National Transport Commission introduced model rail safety legislation that specifies the need for rail operators to provide for the management of rail safety worker fatigue in an overall SMS approach. The development of risk-based approaches led to the development of the Australian standard for risk management (AS/NZ 4360) [48], which has formed the basis of the ISO standard for risk management (ISO 31000) [109]. WHS laws in Australia are crucial, as they must interface and support the regulations that establish the key health and safety duties of employers and employees. The WHS framework is supported by regulations, national compliance and enforcement policies, codes of practice and guidance documents.

New Zealand's *Railways Act* 2005 does not have mandated hours of operation, but requires operators to maintain policies that ensure rail personnel are not suffering from impairment or incapacity as a result of fatigue [149].

In the United Kingdom, a risk-based approach to fatigue was introduced in 2006, removing the prescribed limits on hours of work and rest. The Railways and Other Guided Transport Systems (Safety) Regulations 2006 (ROGS) [150] layout specific employer responsibilities as they relate to establishing the competency and fitness of workers (including evaluation for fatigue) in safety-critical positions (i.e. all duty holders working on a transport system).

In the United States, rail safety legislation relies on prescriptive HoS laws. This includes the maximum on-duty periods, minimum off-duty periods, limitations on consecutive days, and monthly limitations on activity. The legislation also establishes how to calculate time on duty.

The *Rail Safety Improvement Act* of 2008 [151], part of the US Railroad Safety Risk Reduction Program, required all railroads to develop a fatigue management plan by 2012, with subsequent updating and approval by the Secretary every two years. The fatigue management plan is encouraged to be tailored to specific employees and parts of the rail system, and must include up-to-date employee training on human factors and physiological factors of fatigue and countermeasures. It is to include ways to identify and treat employees with sleep disorders or other medical disorders than can cause fatigue. It must also include:

- Procedures for employees who have been in emergencies or other fatiguing activities;

- Scheduling practices that reduce sleep loss and debt;
- Procedures that minimize accidents during periods of the circadian rhythm that have been linked to increased accidents;
- Alertness strategies to combat fatigue while on duty, possibly including napping policies;
- Environments for restful sleep provided by the carrier;
- Increased consecutive hours of off-duty rest where the employee will be unreachable by the carrier; and
- Procedures to avoid disrupting employee's rest cycles.

As of 2011, regulations for commuter and passenger rail services are instructed to use FRA-approved biomathematical modeling software specifically designed to predict human performance and fatigue, as a way to identify schedules with unacceptable levels of fatigue exposure [59].

Throughout the rail industry, the FRA is now promoting the use of more comprehensive safety systems whereby companies are to consider the maintenance systems, the human capital, and the organizational systems influencing safety culture, as opposed to the historical focus on work/rest rules and regulations [33].

Marine

Internationally in the marine sector, initiatives have primarily focused on establishing prescriptive limits on the work and rest hours of seafarers, especially watch keepers [33, 152]. The IMO, who Canada actively cooperates with, has several resolutions and guidance materials relating to seafarer fatigue [63]. In 2002, the *International Labour Organization Convention 180 – the Seafarers' Hours of Work and Manning of Ships Convention*, was enacted to set prescriptive limits. Two directives (Directive 99/63/EC and Directive 99/95/EC) issued by the broader based European Working Time Directive, relate to the working time of seafarers [153, 154].

In Canada, section 320 of the *Marine Personnel Regulations* lays out specific work/rest limits for the master and every crew member of a Canadian vessel, including fishing vessels [61]. Although several other countries (UK, Denmark, US) have regulations to limit the hours of work and rest of seafarers, many have had difficulty developing workable prescriptive HoS regulations for the fishing industry due to specific operating challenges [33].

Fatigue management and awareness training materials have been developed for marine pilots in response to Canada's TSB Recommendation M96-18 (i.e., "...develop and implement an awareness program to provide guidance to dispatching staff and pilots on reducing the adverse effects of fatigue on job performance") and TSB Recommendation M99-04 (i.e. "The Department of Transport and the Canadian pilotage authorities develop and implement an awareness program to provide guidance to operational employees, including pilots, on reducing the adverse effects of fatigue on job performance"). These materials include the *Fatigue Management Guide for Canadian Marine Pilots* (TP 13959) and the Trainer's Handbook (TP 13960) [39, 62]. On 31 May 2018, the TSB issued Recommendations M18-01 and M18-02 to help ensure that watchkeepers, whose work and rest periods are regulated by the *Marine Personnel Regulations,* have the tools needed to recognize and address the risks of fatigue [61].

The United States Coast Guard has developed a Crew Endurance Management System to mitigate errors and degraded performance associated with fatigue in the marine environment [64]. The Coast Guard has also worked with the American Waterways Operators to develop guidance on *Developing a Fatigue Risk Management Plan: A Guide for Towing Vessel Operators* [155]. This guide is intended to help member companies develop a fatigue risk management plan to incorporate into their existing SMS.

Nuclear

In Canada, the topic of *Fitness for Duty: Managing Worker Fatigue* (REGDOC-2.2.4) is part of the CNSC's Human Performance Management series of regulatory documents, which covers human factors, personnel training, personnel certification, and fitness for duty [40]. It contains programmatic elements applicable to the broad populations including:

- Establishing limits on hours of work and recovery periods;
- Identifying and managing worker fatigue;
- Authorities, accountabilities and responsibilities;

- Training and education;
- Control of changes to shift schedules;
- Problem identification and resolution; and
- Assessment and continual improvement. It also contains limits on hours of work and recovery periods applicable to safety-sensitive positions.

In the United States, regulations on work hours for nuclear personnel are found in 10 *Code of Federal Regulations* (CFR) Pt. 26 [63]. These regulations take into consideration numerous factors that can influence fatigue and not just work hours, including such variables as sleep disorders and circadian rhythm variations. The regulations stipulate information regarding the policies, procedures, training, recordkeeping, reporting and auditing of the FMP. There is information on calculating employees' work hours and some caps of work and break durations. It provides guidance for what must be done when an employee declares him or herself as not fit for duty due to fatigue. Requirements to conduct fatigue assessments are also stipulated. The U.S. Nuclear Regulatory Commission (USNRC) published Regulatory Guide 5.73, "Fatigue Management for Nuclear Plant Personnel" in March 2009, which defines a method to comply with 10 CFR Pt. 26 [67]. With some considerations, it endorses NEI 06-11 [Revision 1] *Managing Personnel Fatigue at Nuclear Power Reactor Sites,* published by the Nuclear Energy Institute (NEI) in October 2008 [68].

Oil and Gas

There are no regulations for fatigue management in Canada's mining or oil and gas industries. However, there are several relevant guidance documents and codes of practice.

The Canadian Association for Petroleum Producers (CAPP), in a joint effort with the Canada-Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB), developed a "Code of Practice – Fatigue Management in the Canada-Newfoundland and Labrador Offshore Petroleum Industry" [69]. The Code of Practice summarizes the requirements for defining and managing fatigue and the roles and responsibilities of operators, employers, supervisors and employees. It also summarizes the applicable regulatory requirements and provides information on the process for requesting an exemption to the day of rest provision, section 22 (1) of the *Newfoundland and Labrador Labour Standards Act.*

In Sept 2013, several associations of the upstream oil and gas industry signed a "Fatigue Risk Management Guiding Principles" document to recognize that fatigue is an industry issue. This led to Energy Safety Canada's (formerly ENFORM) development of "Fatigue Risk Management – A Program Development Guide" [10] to help organizations design and implement an effective FRMP. In the pipeline sector, the CSA Express Document (CSA EXP248-2015), *Pipeline human factors* [70]) includes a chapter addressing fatigue management and guidance for operating companies with reference to having a FMP.

The International Association of Oil and Gas Producers (IOGP) and International Petroleum Industry Environmental Conservation Association (IPIECA) have developed several guidance documents. These include:

- Managing fatigue in the workplace. A guide for oil and gas industry supervisors and occupational health practitioners [71];
- Performance indicators for fatigue risk management systems [72];
- Assessing risks from operator fatigue [73];
- Fly-in, fly-out operations [74].

The Energy Institute, a global chartered professional membership body for the energy industry worldwide, released a guidance document titled, *Managing fatigue using a fatigue risk management plan* (FRMP) in 2014 to provide introductory information on the causes of fatigue and its management. It also provides guidance to managers on the design and implementation of an FRMP [75].

In the United States, the American Petroleum Institute's (API) standards program, accredited by the American National Standards Institute (ANSI), developed a recommended practice (RP755) on *Fatigue Risk Management Systems for Personnel in the Refining and Petrochemical Industries* [76]. This recommended practice provides guidance to all stakeholders (e.g., employees, managers, supervisors) on understanding, recognizing and managing fatigue in the workplace.

Owners and operators should establish policies and procedures to meet the purpose of this recommended practice. It is based on the FRMS approach but also provides HoS guidelines. Other initiatives in the United States include a CDC [156] and NIOSH [156] fact sheet directed to oil and gas workers to address fatigued driving.

Focusing more on controller performance, in 2006 the US Congress passed *The Pipeline Inspection, Protection, Enforcement and Safety (PIPES)* Act that required that operator plans covering human factors include a maximum HoS limit [77]. The final rule from the U.S. Department of Transportation's Pipeline and Hazardous Materials Safety Administration (PHMSA) requires operators of pipeline facilities to ensure that human factors such as adequate training and fatigue are recognized and managed in a systematic manner. This involves the operators making sure that controllers have the information, tools, processes, and procedures necessary to perform their duties. The final rule from PHMSA, published in the Federal Register (74 FR 63310) states that, "pipeline operators must implement measures to prevent fatigue that could influence a controller's ability to perform as needed. Operators will need to schedule their shifts in a manner that allows each controller enough off-duty time to achieve 8 hours of continuous sleep".

Australia's National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) developed a guidance note in 2014 to assist duty holders to achieve legislative compliance by reducing fatigue-related risk to a level that is as low as reasonably practicable through the implementation of a FRMS [17]. The guidance note cites the *Commonwealth Offshore Petroleum and Greenhouse Gas Storage (Safety) Regulations* 2009 that stipulates, "a person must not allow, or require, a member of the workforce, who is under the person's control, to work for a continuous or successive period of time that could reasonably be expected to have an adverse effect on the health or safety of that member of the workforce or other people at or near the facility" [158].

More recently, the Australian Pipelines and Gas Association released "Fatigue Risk Management Guidelines: A Guide to Proactively Managing Fatigue in the Australian Pipelines and Gas Association" [159]. The guidelines were developed with the intent to encourage the adoption of uniform fatigue management practices across the industry.

Healthcare

In 2014, the Canadian Medical Association developed a policy on the management of physician fatigue [78]. The policy presents recommendations that include education, access to self-awareness and standardized handover tools, schedule optimization, and the implementation of fatigue risk management plans.

A National Steering Committee on Resident Duty Hours (2013) developed a report, "Fatigue, Risk and Excellence: Towards a Pan-Canadian Consensus on Resident Duty Hours", that recognized the many factors that contribute to resident fatigue and stressed that a one-size-fits-all approach to minimizing fatigue and fatigue-related risk is insufficient [160]. In response to these key findings, a FRM project was launched in 2013 with the aim of producing the first national resource on FRM in Canadian Postgraduate Medical Education (PGME). The first project output, the FRM Toolkit, is a nonprescriptive resource that outlines strategies for mitigating fatigue-related risk that can be adapted to specific contexts and specialties [79].

To determine prevailing norms across Canada on nursing fatigue and patient safety, the Canadian Nurses Association (CNA) and the Registered Nurses' Association of Ontario (RNAO) conducted a broad environmental scan that included interviews, a national survey and a literature review. The resulting "Nurse Fatigue and Patient Safety" research report included recommended solutions targeted to the system, organizations and practitioners [14]. Subsequently, a best practice guideline, *Preventing and Mitigating Nurse Fatigue in Health Care* was developed to provide:

- "Evidence-informed recommendations for individuals, systems, and organizations to identify and describe practices that prevent and mitigate fatigue for nurses and other health-care professionals;
- System resources that support practices to prevent fatigue;
- Organizational cultures, values and resources that support effective practices to prevent fatigue;
- Personal resources that can be used to prevent or mitigate fatigue; and

- Anticipated outcomes when fatigue is effectively managed, thereby fostering healthy work environments" [42].

Defence

Defence Research and Development Canada developed *General Recommendations on Fatigue Risk Management for the Canadian Forces [*41]. The recommendations were developed in response to an Advisory Publication (ADV PUB Number ASMG 6000, 7 Jan 2010) on Fatigue Countermeasures in Sustained and Continuous Operations, which recommended that all Air and Space Interoperability Council (ASIC) nations should have national policies regarding fatigue management [161]. The document focuses on the management of sleep hygiene and circadian entrainment, rather than physical, muscle fatigue, or fatigue at the cellular level. A stratified approach is adopted to ensure that promotion of sleep is the priority under routine fatigue management, followed by generally approved pharmacological intervention.

The United States Army addresses fatigue as part of their "Combat and operational stress control manual for leaders and soldiers" [80]. The Australian forces address fatigue as part of their *Fatigue Management During Operations: A Commander's Guide* [81].

A.2 Summary of FRM Guidance from Other Industry Sectors

Some industry sectors had little or no fatigue risk management guidance developed from a Canadian perspective, however research was available on the effects of fatigue in these industries. These sectors are summarized in Table A.1.

Table A-1: *FRM Guidance from Other Industry Sectors*

Industry	Stakeholder Input
EMS/Paramedics	Canadian efforts have leveraged existing guidance from Australia's "Emergency services: guideline for risk managing fatigue" [162] and ongoing efforts by the US National Association of State EMS Officials Project to create an evidence-based guideline for fatigue risk management tailored to EMS operations [163].
Firefighters	The topic of fatigue is gaining traction as part of discussions about the full scope of "Fit for Duty." Results from a recent focus group conducted by the Alberta Municipal Health and Safety Association (AMHSA), indicated that fatigue should be considered as part of Fit for Duty along with physical fitness, mental health, and drugs and alcohol [164]. As well, there is a need for training and education, consideration of fatigue in incident investigations, and guidance that address multiple jobs and extended hours.
Agriculture	Canada's agriculture sector does not have guidance on fatigue management aside from driver training related to the transportation of fertilizer through Fertilizer Canada. To help producers manage their business risks, including fatigue, the Canadian Agriculture Safety Association developed a farm management tool called the Canada FarmSafe Plan in 2011 [165]. Fatigue is gaining recognition as an emerging health and safety challenge in Australia given that peak times such as harvest, when growers put in extremely long hours, are high-risk periods for workplace safety [166, 167]. In Canada, the Dairy Farmers of Canada conducted a Canadian Sleep Review in 2016 [168] to examine the state of sleep behaviours and attitudes in Canada. A Canadian Sleep Review Panel was also assembled to develop discussion points and advice on the topic of sleep. Results indicated that 74% of Canadians are functioning with chronic sleep debt, and that our current sleep culture in Canada is not conducive to the best possible sleep.
Forestry	Canadian efforts have leveraged guidance developed in Australia by Worksafe Victoria on "Fatigue Management Guidelines for the Forestry Industry." [169]. Further, fatigue management was a recurring topic at safety conferences conducted by the BC Forest Safety Council, and safety alerts have been provided to raise awareness of sleep and fatigue impairment [170].
Manufacturing	The Manufacturing Safety Alliance of BC refers to the dangers of fatigue in the workplace [171], and the Safety Association for Saskatchewan Manufacturers (SASM) promotes and distributes AlertMeter software, a modified psychophysical test that identifies indicators of impairment [172]. The SASM does not, however, provide additional guidance related to fatigue management.
Film and Performance Arts	In 2012, Actsafe Safety Association developed guidance to address extended work hours with a focus on driving while fatigued. In 2015, the Union of BC Performers (UBCP) branch of the Alliance of Canadian Cinema, Television and Radio Artists (ACTRA), initiated a Fatigue, Work, Health and Lifestyle survey that was distributed through six unions/guilds representing the film and performing arts sector [173]. Subsequently, Actsafe issued 90 recommendations for managing fatigue in the motion picture industry for distribution to British Columbia's motion picture and television industry [174].
Chemical Processing Industry	The chemical processing industry follows the API RP 755 guidelines in the United States [175].
Construction	"Fatigue Management Program Guidelines" were updated by the Alberta Roadbuilding and Heavy Construction Association (ARHCA) in 2008 to ensure that management, supervisory personnel and employees understand what fatigue is, how extended hours of work or consecutive days of work can affect fatigue, and how to effectively deal with worker fatigue [176]. Resources include a "Fatigue Risk Management Manual for the Heavy Civil Construction Industry in Alberta" with checklists and training presentations for employees and employers [177].
Law Enforcement	While there is no guidance in Canada, there have been initiatives conducted to address fatigue in law enforcement. The Calgary Police Services conducted a sleep research project that involved trials of new shift schedules, health screening, surveys and training [178]. The Royal Canadian Mounted Police (RCMP) also conducted a pilot study in 2016-2017 that suggested that a fatigue management training program resulted in positive sleep health benefits [179]. The Toronto Police Service developed an online course on fatigue management that was made available to all police services via the Canadian Police Knowledge Network (CPKN) [180]. In 2017, Halifax Regional Police (HRP) conducted a worker fatigue survey and a fatigue gap analysis of their current SMS. In-house trainers were established to provide education to the workforce [181]. In Australia, police services refer to fatigue management guidance developed by the Heavy Vehicle National Law (HVNL) related to driver fatigue management [53].
Municipalities	While no formal guidance was found on fatigue in municipalities, some municipalities and their respective safety associations have developed training on fatigue management. In 2018, the BCMSA responded to requests from its membership and developed two separate training initiatives; one for supervisors and safety and health committees and one for leadership/management. The AMHSA sponsored focus groups on the topic of fit for duty in 2016 and currently provide online training on fatigue management for drivers and supervisors. Training is also provided on HoS, including an overview of Canada's Federal Hours of Service regulations and/or the provincial HoS limits. In 2017, the Halifax Regional Municipality designed and implemented a train-the-trainer program related to fatigue management in the workplace. The training program was conducted to raise awareness of the issues related to fatigue and to introduce tools for supervisors and employees to help manage the issue and reduce the stigma in the workplace. The target groups were public works and transit operations.

CSA Group Research

In order to encourage the use of consensus-based standards solutions to promote safety and encourage innovation, CSA Group supports and conducts research in areas that address new or emerging industries, as well as topics and issues that impact a broad base of current and potential stakeholders. The output of our research programs will support the development of future standards solutions, provide interim guidance to industries on the development and adoption of new technologies, and help to demonstrate our on-going commitment to building a better, safer, more sustainable world.

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