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How shift scheduling practices contribute to fatigue amongst freight rail operating employees: Findings from Canadian accident investigations

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ABSTRACT

Canada's freight rail system moves 70% of the country's surface goods and almost half of all exports (RAC, 2016). These include dangerous goods. Anonymous survey of freight rail operating employees conducted by the Teamsters Canada Rail Conference (TCRC, 2014) revealed that many do not report getting enough sleep because of their work schedules, and that fatigue may be affecting their performance at work. Besides general impairments in attention and cognitive functioning, fatigue in railway operating employees slows reaction time to safety alarms and impairs conformance to train operating requirements. Shift scheduling practices can contribute to sleep-related fatigue by restricting sleep opportunities, requiring extended periods of wakefulness and by disrupting daily (circadian) rhythms. The primary goal of accident investigation is to identify causal and contributing factors so that similar occurrences can be prevented. A database search of Transportation Safety Board (TSB) rail investigation reports published in the 21-year period from 1995 to 2015 identified 18 that cited sleep-related fatigue of freight rail operating employees as a causal, contributing, or risk finding. This number represents about 20% of TSB rail investigations from the same period in which a human factors aspect of freight train activities was a primary cause. Exploration of accident themes suggests that management of fatigue and shift scheduling in the freight rail industry is a complex issue that is often not conducive to employee circadian rhythms and sleep requirements. It also suggests that current shift scheduling and fatigue management practices may be insufficient to mitigate the associated safety risk. Railway fatigue management systems that are based on the principles of modern sleep science are needed to improve scheduling practices and mitigate the ongoing safety risk.

1. Introduction

Fatigue is pervasive in today's society, especially in the transportation industry. Most people need between seven and eight hours of continuous sleep every night to feel well rested; however many Canadians report getting fewer than six hours' sleep per night, and being dissatisfied with the quality of the sleep they do obtain (Morin et al., 2011). One online survey found that nearly 58% of Canadian respondents said they felt tired "most of the time." (CBC News, 2011). A 2012 poll conducted by the U.S. National Sleep Foundation, a leading sleep health organization, found that many transportation workers reported not getting enough sleep because of their work schedules (NSF, 2012); that is, they might work too many hours at a stretch, or their work hours, which are irregular, coincide with normal sleep times. The NSF poll found that, compared to non-transportation workers, train operators and airline pilots were the most likely to report sleep-related job performance problems. Research of U.S. railway operations (Gertler et al., 2013) using logbook entries has found that railroad workers, as a group, are more likely than other working Americans to get less than 7 h of total sleep on workdays. Workers in freight rail operations were found to have the highest exposure to the risk of fatigue due to unpredictable schedules, longer shifts, and more nighttime work compared to other railway worker groups.

Disruptions to sleep or sleeping patterns in personnel occupying safety critical positions may cause performance detriments that increase the risk of incidents and accidents. Disruptions include acute sleep disruptions, chronic sleep disruptions, continuous wakefulness, circadian rhythm disruptions, sleep disorders or other medical and psychological conditions, illnesses or drugs that affect sleep or sleepiness.

Besides general impairments in attention and cognitive functioning, fatigue in railway operating employees slows reaction time to safety alarms (Hildebrandt et al., 1974) and impairs conformance to train operating requirements, including increasing fuel use, heavy brake applications and maximum speed violations (Dorrian et al., 2007). International research on fatigue in the rail industry confirms the

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relationship between fatigue and impaired train operating performance. For example, research conducted on behalf of the U.S. Federal Railroad Administration (FRA) (Gertler et al., 2013) found that the risk of being involved in a human factors-related railway accident was elevated 11% to 65% above chance by a worker's exposure to fatigue. Parenthetically, the amount of sleep and time of day when sleep occurred (both determined by shift schedule) were found to account for between 85% and 96% of workers' fatigue exposure. Similar results have been found in research conducted by the U.K. Rail Safety and Standards Board (RSSB) (Bowler & Gibson, 2015). Analysis of data from 246 high risk railway incidents in the U.K. confirmed the contribution of fatigue to impaired operational performance. Fatigue was identified as either a contributing or performance shaping (aka "risk") factor in 21% of incidents reviewed. Of these incidents, 80% involved locomotive operators, who were also overrepresented (compared to signalers or maintainers) in terms of experiencing "work-related", as opposed to "home-life related", fatigue.

Shift scheduling practices can contribute to sleep-related fatigue by:

1 restricting opportunities to obtain sufficient restorative sleep (acutely or chronically);
2 requiring extended periods of wakefulness; and/or
3 disrupting daily (circadian) rhythms.

Canada's freight rail system is vital, moving about 70% of the country's surface goods, including dangerous goods, and almost half of all exports (RAC, 2016). It is important, therefore, to limit accident and incident risk in the freight rail system. One of the goals of accident investigation is to determine the causal and contributing factors that led to an accident so as to minimize the likelihood that a similar accident will happen in future. To assist its investigators, the TSB has published and updated a guide to investigating for fatigue since 1997. However, while there are typically between 1200 and 1400 rail occurrences reported to the TSB each year under mandatory reporting requirements, practical considerations dictate that only a portion (about 1%) are fully investigated by the TSB and result in a published TSB report. Therefore, it is challenging to estimate statistically the prevalence of fatigue-related accidents in the railway operating context. Nevertheless, review of those investigations where fatigue was concluded to have played a role can increase our understanding of the issue, especially when considered in light of recent advances in sleep science.

To this end, the goal of the present research was to review rail investigation reports published in the 21-year period from 1995 to 2015 (the most recent year for which data were available), search for key words, and produce a list of those where fatigue in freight rail operational employees was causal, contributory or determined to present a risk. Report findings and recommendations relating to fatigue of freight railway operating employees were explored, and grouped according to theme to better understand the primary issues affecting fatigue in freight rail operating employees.

2. Method

2.1. Database review

The TSB's Railway Occurrences Database System (RODS) stores information on federally regulated railway occurrences in Canada. Data fields in RODS include, for example, accident location, railway, track and train type, train and road speed, crossing characteristics, train and road vehicle occupant injuries and fatalities, and a summary of each occurrence. A full-text search was conducted on approximately 630 rail occurrence reports dating from 1995 to 2015. Key word combinations were searched for proximity. Word combinations and variants included:

- Sleep(y|ing) + fatigue(d)
- Rest(ed|ing) + fatigue(d)
- Work/rest + fatigue(d)
- Alert(ness) + fatigue(d)
- Alert(ness) + sleep(y|ing)

Key word combinations were also used to exclude some records; for example, those that included:

- Fatigue + crack(ing)
- Fatigue + fail(ure)

Occurrences were not restricted to those from a given geographical area. Those occurrence summaries identified by the search and any associated investigation reports were reviewed and scrutinized for themes. The fatigue-related themes sharing commonality were noted and grouped.

To get a sense of the proportion of investigations where a human factors aspect of freight train activities was a primary cause that also involved fatigue of the operating crew, all rail occurrences from the year 1995 to 2015 were reviewed and coded. Since 1995, there had been 90 rail investigations in which a human factors aspect of freight train activities was noted as a primary cause.

3. Results and discussion

The RODS database contained 630 searchable rail occurrence reports for the period 1995 to 2015. From this initial data set, 217 reports were identified for further review based on the presence in the report text of key words relating to fatigue. Reports were triaged based on whether they referenced fatigue in materials, or mental or physical fatigue in humans. Of 217 reports, 84 were excluded because they dealt with metal fatigue, and 133 were retained. These 133 reports were studied, and 23 reports were identified where fatigue was deemed to have been a factor in the events of the occurrence (representing a causal, contributing, or risk factor). One report was removed from the data set because it dealt with passenger train operations (not freight). Another four reports were removed because the parties involved in the occurrences were other than train operating crew (i.e., rail traffic control, inspector, or maintenance crews).

From the initial data set, 18 occurrence reports[1] remained where operator fatigue was identified as a factor to the occurrence. This number represents about 20% of the 90 TSB rail investigations in which a human factors aspect of freight train activities was noted as a primary cause. The 18 investigation reports were reviewed, and seven common themes were identified. These seven themes are summarized next.

3.1. Themes from TSB investigation reports

Seven themes were extracted from the 18 TSB rail reports that identified sleep-related fatigue of freight railway operating personnel as a causal, contributing, or risk factor. Themes include:

1 Disruption of the normal sleep cycle,
2 The varied and unpredictable nature of railway shift scheduling,
3 Insufficient rest periods between shifts,
4 Extended periods of continued wakefulness due to shift length,
5 Cumulative effects of working extended hours over the long term,
6 Pressures on crews not to refuse shifts because of fatigue, and
7 Ineffective fatigue countermeasures.

Broadly, the seven themes fall into one of two general categories of challenges facing railways in efforts to effectively mitigate fatigue in

[1] TSB investigation reports R95S0021, R95V0218, R96Q0050, R96W0171, R97C0147, R98V0183, R99E0023, R03W0169, R05C0082, R06W0079, R07E0129, R07V0213, R09W0259, R10E0096, R10T0213, R11D0075, R11E0063, R14V0215.

freight train operating employees: 1) shift work and its management and 2) implementation of fatigue safety countermeasures. Although identification of fatigue risk and its management likely matured and became more prevalent in recent years, the distribution of reports across the 21-year period selected was fairly consistent, suggesting that any time bias inherent in the data due to, for example, increased awareness of fatigue and its consequences, was minimal. The themes and relevant, associated occurrences, are described next within this context.

3.1.1. Shift work and its management

Disruption of the normal sleep cycle. People have numerous daily (circadian) biological rhythms that influence the body's internal and external functions. Performance and cognitive functioning are generally worst during the period when circadian rhythms dictate sleep. Performance on specific measurements such as reaction time (Tilley et al., 1982), arithmetic and signal detection (Tepas et al., 1981) and reaction to train safety alarm alerts (Hildebrandt et al., 1974) have all been demonstrated to be worst during the night.

Several TSB rail investigations have highlighted safety deficiencies related to shift scheduling, which have resulted in sporadic disruptions to normal sleeping patterns and effects on performance and safety. For example, in TSB investigation number R11D0075, on 24 September 2011 at approximately 0316 Eastern Daylight Time, a Canadian National (CN) Railway train derailed 6 cars near Pointe-Saint-Charles, Quebec. Findings indicated that crews were working variable, unpredictable schedules that resulted in them being exposed to an increased risk of diminished alertness associated with the desynchronization of their circadian rhythms. Similarly, in TSB investigation number R14V0215, on 15 November 2014, a CN freight train proceeding west on the Skeena Subdivision in British Columbia experienced an undesired emergency brake application. Upon inspection, it was discovered that the trailing locomotive had derailed along with 8 intermodal container cars (22 platforms). Findings indicated that crew members were fatigued at the time of the occurrence, as they had been experiencing highly variable shift start times, which resulted in circadian rhythm disruptions in the days prior to the occurrence. This most likely affected their ability to recognize the significance of an alarm and an earlier-than-expected associated announcement.

Work shift start time variability can desynchronize circadian rhythms due to changes in sleep-wake patterns (Pati et al., 2001). Desynchronization occurs because each biological rhythm adapts to a new sleep-wake pattern at a different rate (Graeber, 1989). For those who work continuous night shifts, circadian patterns may change and adapt over time. However, for those who work only occasional nighttime shifts, circadian patterns will not adapt to working at night. In general, researchers have found that the adjustment of the human circadian system resulting from changes to the sleep-wake pattern occurs at a rate of 1 to 1.5 h per day. Adjusting from being awake during the day to being awake at night, a 12-hour difference, could take between 12 and 18 days for complete adjustment to take place and optimum performance to return. Working only a few night shifts, especially sporadically such as on shifts with variable start and finish times, will not result in optimum circadian adjustment, and performance will continue to be affected by circadian lows (Klein & Wegmann, 1980; Tilley et al., 1982).

Circadian desynchronization can cause fatigue, daytime sleepiness, psychomotor impairment, insomnia, other sleep disturbances, reduced cognitive skills, and muscle fatigue (Anch et al., 1988). Such disruptions to sleep or sleeping patterns in personnel occupying safety critical positions may cause performance detriments that increase the risk of incidents and accidents. For train operators, this may include slow reaction times, late braking and poor conformance to train operating requirements (Hildebrandt et al., 1974; Dorrian et al., 2007).

The varied and unpredictable nature of freight railway shift scheduling. Most freight rail operating employees work flexible (as opposed to set) work schedules. The timing of freight train schedules and, consequently, work shifts, depends on a number of factors, including but not limited to: market demand and availability, weather, unexpected employee illness, and accidents. Variable and unpredictable scheduling makes it difficult for train crew to obtain an adequate amount of good quality sleep, as available sleep periods occur across varying circadian rhythm highs and lows. Variable and unpredictable sleep times can also be difficult to manage when living with families that have daytime commitments, such as mealtimes, school runs and homework. It is also difficult to obtain sleep when anticipating an event such as a work call or when shift start times have changed and an operator has to force unplanned sleep in order to be awake for a shift at an unexpected time.

Several TSB rail investigations highlighted safety deficiencies related to varied and unpredictable scheduling in freight rail operations, which have resulted in operators obtaining insufficient rest and sleep that has affected performance and safety. For example, in TSB investigation number R98V0183, on 01 October 1998 at approximately 0442 Pacific daylight time, two CN freight trains collided on the Ashcroft Subdivision at Basque, British Columbia. The eastward freight train proceeded on the main track past a stop signal and collided with the side of the westward freight train, which was proceeding into the siding. Findings indicated that *both* crew members of the occurrence train may have experienced a microsleep as a result of fatigue resulting from varied and unpredictable crew scheduling.

Investigations into three freight train derailments, occurring in 2003 (R03W0169), 2009 (R09W0259) and 2011 (R11E0063), all involving Canadian Pacific (CP) Railway trains, found that crews were fatigued due to shift scheduling factors. In R03W0169, it was noted that crewmembers may be required to work variable, unpredictable schedules, often for their entire working lives, as a result of the nature of railway operations. This increases the probability that freight train crews will work while in a long-term, chronically fatigued state, increasing fatigue-related errors. In R11E0063, scheduling was noted to have reduced crew alertness, leading to inappropriate control of the train. This investigation concluded that, despite the availability of Work/Rest Rules (Transport Canada, 2011a), work scheduling practices for train crews continued to be a challenge for employers and employees in the railway industry. An example of scheduling issues found during another (unnamed) investigation, even though the crew was operating within Work/Rest rules requirements, was such that:

> In the two weeks prior to the day of the occurrence, one crew member had a mix of day and night shifts, creating sleep opportunities starting at 1200, 1200, 0200, 2000, 0400, 0300, 1300, 1300 and around 0700 on the day of the occurrence. In the day prior to the occurrence, the operator had had the opportunity to sleep at night but, in the four days prior, he was either starting or finishing his shift between the hours of 0000 and 0600. On the day of the occurrence, the operator had slept and prepared to work what was expected to be a late afternoon shift. However, the shift did not start until 2330, upon which time the operator had been awake for many hours. As the shift started late, it also finished late, which meant that the operator was still working at 0500–0600, a period in which he had anticipated that he would be sleeping. On the day of the occurrence, the operator worked through the entire period of 0000–0600, something that he had not previously done in six weeks.

Freight trains often operate on an unscheduled basis and, consequently, crews may be called for trips on an 'as required' basis. Trips can be assigned to crews in subdivision 'pools' based on a first-in, first-out system. When crewmembers finish a trip, their names are placed back into the pool list for reassignment to their next trip. Since freight trains are not scheduled, crews are required to work out from train line-ups an approximate arrival and departure time for their next trip, albeit these train line-ups are not intended for use as a scheduling tool. Times can change dramatically within a short period of time depending upon factors such as delays, the number of slow orders in effect, the number of mechanical problems, track repairs and cancellations. These changes increase the unpredictability of a train's arrival time and the associated call time(s) for crew.

Insufficient rest periods between shifts. Individual sleep needs are unique, but over 90% of the population needs between 7 and 8 h of sleep per 24-hour day to maintain alertness. When we do not get enough sleep, a sleep debt develops. The degree of performance impairment increases as sleep debt increases. The seriousness of even a small sleep debt can be significant. During the week following the change from standard time to daylight savings time, for example, there is typically an 11% increase in the number of road traffic accidents. By contrast, the week following the change from daylight savings time to standard time typically shows a decline in the number of accidents.

Sleep debt is cumulative. Getting an hour less than one's sleep requirement one night results in a one-hour sleep debt. Repeating this for five nights in a row generates about the same symptoms and performance impairments as losing five hours of sleep in one night. The only restorative rest is sleep. People who do not get enough sleep, or whose sleep is of poor quality, become fatigued and their performance suffers. Diet, exercise, rest without sleeping, and varying workload are not effective countermeasures to fatigue in the long term. Interrupted or poor quality sleep will not restore alertness either. The only way to restore performance is to sleep.

Insufficient rest periods between operating shifts have been documented in several TSB rail investigations. For example, in TSB investigation number R95V0218, on 01 October 1995 at approximately 0640, CP freight train 819, proceeding west on the Mountain Subdivision at Greely, British Columbia, collided head-on with CP train 996, proceeding east, at Mile 119.9. The lead locomotives of both trains were extensively damaged. Crew members of both trains sustained minor injuries. The TSB determined that the collision occurred when the crew of train 819 did not take appropriate action in response to a 'Clear to Stop' signal approaching Greely and the 'Stop' signal at Greely, and operated head-on into train 996. The crew of train 819 had become impaired by fatigue due to excessive waking hours without a restorative rest period. Localized dense fog present at the time of the collision was also found to have restricted the visibility of the signal at Greely.

Extended periods of continued wakefulness due to shift length. Just as insufficient rest periods between work shifts can contribute to fatigue by increasing sleep debt, so too can extended periods of continued wakefulness due to shift length that do not allow for sufficient rest to be obtained. Several TSB reports were identified in the data set whereby fatigue resulting from excessive shift length played a causal or contributory role. For example, in TSB investigation number R03W0169, on 19 October 2003 at 2318 central daylight time, CP freight train 202-16, eastbound for Toronto, Ontario, came to a stop with two double stack container cars derailed at Mile 86.5 of the Kaministiquia Subdivision, near Carlstadt, Ontario. There were no injuries and no dangerous goods involved in the occurrence. However, it was concluded that, because the Work/Rest Rules for Rail Operating Employees (Transport Canada, 2011a) permit consecutive hours of wakefulness in excess of 18 h with no scheduled rest, there was increased risk of fatigue-related errors and accidents. The same investigation also concluded that the nature of freight rail operations requires crew members to work variable, unpredictable schedules, often for their entire working lives. These unpredictable schedules increase the probability that train crews will be working in a chronically fatigued state, which can lead to errors associated with fatigue. An earlier TSB investigation similarly found that extended periods of wakefulness caused by extended shift length created an increased risk of fatigue and performance decrements. In the R98V0183 occurrence in which two CN freight trains collided on the Ashcroft Subdivision at Basque, British Columbia (described above), findings indicated that both crew members of the eastward train may have experienced a microsleep due to extended shift length. The investigation found that crew fatigue was more pronounced on the second subdivision of extended runs compared to the first, as the distance travelled and time working during one tour of duty was typically doubled. The investigation concluded that the current (at the time - 1998) regulatory requirements respecting mandatory time off-duty and maximum hours of service could result in train crews being in compliance with regulatory requirements but not being sufficiently rested.

Cumulative effects of working extended hours over the long term. Working extended hours repeatedly limits the time available to achieve the rest required to maintain safe operations. This may be either rest at a work location or rest obtained at home. The Work/Rest Rules for Railway Operating Employees (Transport Canada, 2011a) were devised to help ensure that the performance of rail operating employees would not be unduly affected by scheduling and fatigue. Consequently, there are rules on the number of hours a crew member can work without rest. However, several TSB investigations have noted that these rules can be misinterpreted and/or manipulated, resulting in crews routinely exceeding the maximum permissible tour of duty and sometimes repeatedly working up to 18 h with little or no rest breaks. This increases the risk that crew performance will be adversely affected by cumulative, long-term, fatigue. Several TSB rail investigations have highlighted safety deficiencies related to fatigue from working extended hours over the long term. For example, in TSB investigation number R96W0171, on 02 July 1996, at 0351 Central daylight time, an eastward CN freight train was unintentionally diverted onto a spur track at North Battleford, Saskatchewan, colliding head-on with another stationary and uncrewed CN freight train. While fatigue was not considered to have played a direct role in the accident, the eastward train crew's extended tour of duty made them vulnerable to sleep-related performance degradation. The investigation concluded that mandatory rest requirements at the time did not account for time awake before duty, nor did it consider short turn-around scheduling schemes. The TSB raised a Safety Concern as a consequence of the investigation that, although recognizing the concerted effort by the railways and the regulatory body at the time to resolve fatigue and alertness issues, found that implementation of fatigue management initiatives such as CANALERT (Transport Canada, 2010), coupled with a comprehensive hours of service rule, was necessary to alleviate the problem of fatigue in the railway operating environment.

In TSB investigation number R03W0169, when a CP Railway freight train derailed, findings highlighted that the Work/Rest Rules for Rail Operating Employees (Transport Canada, 2011a) permit consecutive hours of wakefulness in excess of 18 h with no scheduled rest, which increased the risk of fatigue-related errors and accidents. This was raised again in 2006 in investigation number R06W0079, when a westward CP Railway freight train derailed near Swift Current, Saskatchewan. Findings highlighted that the interpretation of the Work/Rest Rules for Railway Operating Employees (Transport Canada, 2011a) allowed trips that routinely exceeded 12 h to be planned as two tours of duty, which created a situation in which crews routinely exceeded the 12-hour maximum tour of duty, and instead worked up to 18 h with little or no rest break. The investigation highlighted how regularly extending shift length increased the risk that crew performance would be adversely affected by fatigue.

Pressures on crews not to refuse shifts because of fatigue. The Work/Rest Rules for Railway Operating Employees (Transport Canada, 2011a) requires both the company and the employee to be jointly responsible for fitness for duty. Specifically, it requires the employee to responsibly report for work rested and fit for duty with the intention of being able to sustain alertness throughout the duty period. Typically, if the operator feels fatigued prior to their shift, they have the option of calling in "sick" or unfit. If the operator feels fatigued during their shift, they have the option to request additional rest at the away station. Under exceptional circumstances and usually for illness, they could also request relief prior to arriving at their destination. However, some operators avoid calling in sick, either prior to their shift or during their shift, as this is often logged negatively on their personnel records and it can affect their position on subsequent train schedules, decreasing the probability of work, or of predictable work. The implications of fatigue reporting therefore directly affects the probability an operator will report fatigue. Several TSB rail investigations have revealed circumstances in which crews reported for work despite being knowingly fatigued. For example, in the R98V0183 occurrence, in which two CN freight trains collided on the Ashcroft Subdivision at Basque, British Columbia (described above), findings indicated that the possibility of loss of income from missing a trip motivated employees to report for duty despite having obtained insufficient rest. In two other CN derailment investigations, one in 2007 (R07E0129) and one in 2010 (R10T0213), findings included the risk that crew fatigue may go unreported. R07E0129 highlighted the risk that fatigued train crews may feel compelled to report for work even without having obtained adequate rest. R10T0213 highlighted that, as it is left to employees to determine whether they are fit to work or not, when faced with loss of wage and/or potential company discipline, there is an increased risk that a fatigued employee will accept work, compromising safe train operations.

3.1.2. Ineffective fatigue countermeasures

The effects of fatigue can be mitigated by implementing fatigue countermeasures. Fatigue countermeasures in freight railway operations include many different strategies, from scheduling countermeasures and the development of Fatigue Management Plans (FMPs), to individual self-help guidance, such as, for example, recommendations regarding the consumption of caffeine.

Scheduling countermeasures. The Canadian Work/Rest Rules for Railway Operating Employees (Transport Canada, 2011a) require that railway companies establish and maintain working conditions that allow alertness among operating crews to be sustained throughout the duty period. To address this requirement, the Work/Rest Rules and Transport Canada's Requirements and Assessment Guidelines for Fatigue Management Plans (FMPs) (Transport Canada, 2011b) stipulate that crews should conform to specific scientific-based scheduling practices, which include the following restrictions and mitigations:

Time on duty. Appropriate restrictions on the number of hours employees are allowed to work and the number of hours of rest required.

Shift predictability. Appropriate restrictions on schedules to ensure that work schedules are highly predictable, in an attempt to mitigate the risks associated with poor sleep management.

Periods of drowsiness. There are two periods of maximum drowsiness in every 24-hour period. These periods can vary from one person to another, but the principal drowsiness periods for diurnal (daytime) workers generally occurs between 0300 and 0500 and from 1500 to 1700. During these periods of drowsiness, physiological systems are at their lowest level so a person may have a hard time remaining alert. Transport Canada's Requirements and Assessment Guidelines for FMP (Transport Canada, 2011b) advise providing additional mitigations for those employees working between the hours of 0000 and 0600.

Training. Transport Canada recommends that crews be trained in various fatigue-related subjects such as fatigue and alertness, sleep hygiene, the circadian (body) clock, sleep and performance, sleep schedules and recommended countermeasures to maintain alertness. These countermeasures could include the use of technology aids, napping, breaks, checklists, communication strategies, and the effective use of light, sound and temperature.

Fatigue management plans. Transport Canada highlights that the most critical countermeasure to fatigue is for companies to include a list of recommended and approved alertness strategies in a company's FMP and to have processes and practices in place to ensure that the FMP is effectively managing fatigue.

Despite this guidance, several TSB rail investigations have highlighted continued risks of fatigue as a result of ineffective fatigue-related, shift scheduling countermeasures. Most notably, there were several occurrences where, even though train crews had been working within the limits prescribed and recommended by the Work/Rest Rules (Transport Canada, 2011a) and Transport Canada's Requirements and Assessment Guidelines for FMPs (Transport Canada 2011b), their shift patterns and associated fatigue negatively affected safety. For example, in TSB occurrence R05C0082, a northbound CP freight train derailed 2 locomotives and 24 cars near Bowden, Alberta. The investigation concluded that the regulatory and industry framework for the management of risks related to fatigue may not have adequately protected against the effects of fatigue that result from the work/rest cycle of train crews – in this instance, fatigue that contributed to train handling errors by the locomotive engineer. In 2011, the Transport Canada Requirements and Assessment Guidelines for FMPs document (Transport Canada, 2011b) was issued, but it only addressed work shift predictability, not shift *variability*. As a result, freight rail operating employee scheduling practices after 2011 continued to include shifts that did not allow for sufficient time to biologically adjust circadian rhythms to different shift schedules, increasing the risk of performance decrements. For example, in occurrence R14V0215 (discussed above), whereby a CN train experienced an undesired emergency brake application derailing 8 intermodal container cars, findings indicated that the crew members were fatigued as a result of multiple circadian rhythm disruptions, even though their work shifts were scheduled within the limits of recommended practices.

Although some Canadian railway companies now have FMPs in place, fatigue in freight rail operating crews may still not be effectively managed. Specifically, many crews continue to not receive effective fatigue-related training and, as a result, are unable to prevent, identify or mitigate fatigue in themselves or others. For example, napping is a fatigue countermeasure that, if used appropriately, can effectively mitigate some of the effects of fatigue. However, some rail operating employees think that napping, as a fatigue strategy, is prohibited. As a result, they conceal their napping behaviors and companies remain unaware of the frequency that crews feel the need to nap. On the other hand, some companies may permit napping, but crews are not always sufficiently educated about the associated risks. For example, naps are vulnerable to sleep inertia (Lubin et al., 1976), the post-sleep performance decrements, such as confusion, disorientation, low arousal and deficits in various types of cognitive and motor performance (Ferrara & De Gennaro, 2000), which occur immediately after awakening. Although the duration of sleep inertia is usually short, from 1 to 15 min, some deleterious effects can last 30 min or longer (Dinges et al., 1987). Research indicates that the duration and severity of sleep inertia can be worse if naps are longer, if naps occur during the circadian core body temperature trough or circadian low (normally in the middle of the night for a diurnally-oriented person), when the person is sleep deprived or has been awake for an extended period or when the nap contains or ends with slow-wave sleep (Dinges et al., 1985; 1987). It is therefore important to control both the amount of sleep during any rest period and the amount of post-nap recovery time, in order to offset the effects of sleep inertia.

Finally, processes and practices in place within a railway's FMP to effectively manage fatigue should include provisions for assessing risk related to fatigue that can result from the implementation of new technologies within the rail operating environment. In TSB occurrence R14V0215 (described above), the investigation noted that the implementation of new automated technology affected how the train was operated, changing the number and type of operating tasks during an already low-workload and fatigue-inducing period of the journey. Findings in that investigation noted that implementation of any new operations technology should account for potential associated human factors–related consequences, including fatigue, so that risks can be fully identified and mitigated before an accident happens.

Use of biomathematical models of fatigue and associated fatigue prediction software tools to assess fatigue risk in freight rail operations work schedules and to plan schedules that limit the likelihood of fatigue.

One particular scheduling countermeasure to fatigue in the rail operating environment that deserves special mention is the application of biomathematical models of fatigue and human performance in the planning and evaluation of employees' shift schedules. Biomathematical models of fatigue, developed through laboratory studies of sleep deprivation and restoration, predict levels of cognitive performance as a function of circadian rhythms and sleep deprivation (see Gertler et al., 2013 for a complete review). These models are used by some U.S. railways to predict a worker's level of fatigue and resulting performance degradation based on work schedules. As such, their implementation can limit workers' exposure to fatigue, at least that which results from working challenging shift schedules. In fact, a U.S. federal regulation regarding hours of service of railroad employees who provide commuter and intercity rail passenger transportation (U.S. 49 C.F.R. § 228) requires the use of a validated and calibrated model of human performance and fatigue to analyze work schedules under certain circumstances. The FRA has approved two models for use by railroads: the Fatigue Audit Interdyne™ (FAID) model and the Fatigue Avoidance Scheduling Tool™ (FAST). The effectiveness of FAST in a railroad operational environment has been validated (Hursh et al., 2008). However, the implementation of either the FAST or the FAID systems in Canadian freight rail operating environments more specifically has not been evaluated.

4. Conclusions

Eighteen occurrences from the years 1995 to 2015 resulted in a TSB report that identified fatigue of freight railway operating employees as a causal, contributing, or risk finding. Review of report themes indicates that management of fatigue and shift scheduling in the freight rail industry is a complex issue that is often not conducive to the circadian rhythms and associated sleep requirements of employees. It further suggests that ongoing shift scheduling and fatigue management practices in the freight rail industry may be insufficient to mitigate the associated safety risk.

Transport Canada's Railway Safety Management System (SMS) Regulations, published in 2015, include requirements for railway companies to develop and implement SMS that address risk from fatigue by applying certain principles of fatigue science to their shift scheduling practices. In April 2015, Transport Canada established a three-phase plan for the implementation of the new requirements, and stated that it will consider the results of audit activities and consultation with stakeholders before taking further measures to manage railway crew fatigue.

Transport Canada is currently auditing railways' SMS before taking further measures to manage railway crew fatigue; audits are scheduled to occur up to 2021, but there are limited resources and auditors available. Review of railway fatigue management systems required by SMS regulations needs to be expedited, and further actions taken, to improve scheduling practices and mitigate risk of fatigue. One area of exploration of potential safety benefit is the examination of the Canadian railway industry's use and implementation of fatigue prediction models to freight rail operations employees' shift scheduling practices. While several fatigue prediction models and their associated software are approved by the U.S. FRA to meet shift scheduling requirements of commuter and inter-city rail transit operations (49 C.F.R. § 228), there are currently no requirements for Canadian railways to use these systems, nor are there requirements in either country for the application of these systems within *freight* rail operations.

Even though the railway industry and Transport Canada have known sleep-related fatigue to be a problem for over 20 years, the initiatives taken to-date have been inadequate to fully address the issue. As a result, fatigue has been identified as an item on the 2016 TSB Watchlist of key safety issues in Canada's transportation system, as it continues to pose a risk to the safe operation of trains, particularly freight trains.

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