U.S. Department of Transportation

Federal Railroad Administration

Office of Research, Development and Technology
Washington, DC 20590

The Impact of Commute Times on the Fatigue and Safety of Locomotive Engineers and Conductors

DOT/FRA/ORD-23/17

June 2023

REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 0704-0188*

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
06/15/2023	Technical Report	*May 2018 – February 2023*

4. TITLE AND SUBTITLE	
The Fatigue and Safety of Locomotive Engineers and Conductors	**5a. CONTRACT NUMBER** 693JJ618C000007
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) Naomi J. Dunn and Susan Soccolich	**5d. PROJECT NUMBER**
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Virginia Tech Transportation Institute 3500 Transportation Research Plaza Blacksburg VA 24061	**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Department of Transportation Federal Railroad Administration Office of Railroad Policy and Development Office of Research, Development, and Technology Washington, DC 20590	**10. SPONSOR/MONITOR'S ACRONYM(S)**
	11. SPONSOR/MONITOR'S REPORT NUMBER(S) **DOT/FRA/ORD-23/17**

12. DISTRIBUTION/AVAILABILITY STATEMENT
This document is available to the public through the FRA website.

13. SUPPLEMENTARY NOTES
COR: Mike Jones

14. ABSTRACT
An online survey was developed by the Virginia Tech Transportation Institute and distributed by the Brotherhood of Locomotive Engineers and Trainmen (BLET) and the Sheet Metal, Air, and Rail Transportation workers –Transportation Division (SMART-TD) labor unions to their members. The purpose of the survey was to better understand the factors that contribute to fatigue in locomotive engineers and conductors, and the potential impact on safety. The final dataset comprised 9,084 responses with an almost equal 50/50 split on job role (4,497 locomotive engineers and 4,587 conductors). Both locomotive engineers and conductors reported frequently experiencing fatigue due to factors such as irregular work schedules, long working hours, and night work. In particular, factors associated with scheduling variability, such as greater variation in start times and frequent switching from day to night work, greatly increased the likelihood of locomotive engineers and conductors being characterized as highly fatigued. Fatigue also increased the odds of experiencing fatigue-related safety events at work and during the commute to and from work. The results of this survey indicate the importance of considering commute time in fatigue mitigation and help to highlight other contributors to fatigue.

15. SUBJECT TERMS
Fatigue, safety

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**		72	**19b. TELEPHONE NUMBER** *(Include area code)*

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in)	=	2.5 centimeters (cm)
1 foot (ft)	=	30 centimeters (cm)
1 yard (yd)	=	0.9 meter (m)
1 mile (mi)	=	1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2)	=	6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2)	=	0.09 square meter (m^2)
1 square yard (sq yd, yd^2)	=	0.8 square meter (m^2)
1 square mile (sq mi, mi^2)	=	2.6 square kilometers (km^2)
1 acre = 0.4 hectare (he)	=	4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz)	=	28 grams (gm)
1 pound (lb)	=	0.45 kilogram (kg)
1 short ton = 2,000 pounds (lb)	=	0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp)	=	5 milliliters (ml)
1 tablespoon (tbsp)	=	15 milliliters (ml)
1 fluid ounce (fl oz)	=	30 milliliters (ml)
1 cup (c)	=	0.24 liter (l)
1 pint (pt)	=	0.47 liter (l)
1 quart (qt)	=	0.96 liter (l)
1 gallon (gal)	=	3.8 liters (l)
1 cubic foot (cu ft, ft^3)	=	0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3)	=	0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x-32)(5/9)] °F = y °C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm)	=	0.04 inch (in)
1 centimeter (cm)	=	0.4 inch (in)
1 meter (m)	=	3.3 feet (ft)
1 meter (m)	=	1.1 yards (yd)
1 kilometer (km)	=	0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2)	=	0.16 square inch (sq in, in^2)
1 square meter (m^2)	=	1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2)	=	0.4 square mile (sq mi, mi^2)
10,000 square meters (m^2)	=	1 hectare (ha) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gm)	=	0.036 ounce (oz)
1 kilogram (kg)	=	2.2 pounds (lb)
1 tonne (t)	=	1,000 kilograms (kg)
	=	1.1 short tons

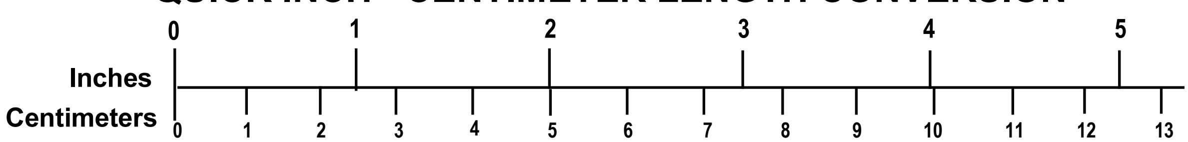
VOLUME (APPROXIMATE)

1 milliliter (ml)	=	0.03 fluid ounce (fl oz)
1 liter (l)	=	2.1 pints (pt)
1 liter (l)	=	1.06 quarts (qt)
1 liter (l)	=	0.26 gallon (gal)
1 cubic meter (m^3)	=	36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3)	=	1.3 cubic yards (cu yd, yd^3)

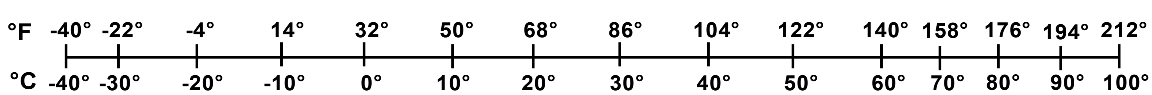
TEMPERATURE (EXACT)

[(9/5) y + 32] °C = x °F

QUICK INCH - CENTIMETER LENGTH CONVERSION



QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSIO



For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50 SD Catalog No. C13 10286

Updated 6/17/98

Acknowledgements

The authors would like to thank the Brotherhood of Locomotive Engineers and Trainmen (BLET) and Sheet Metal Air, and Rail Transportation Workers – Transportation Division (SMART-TD) labor unions for their input during survey development and assistance with distribution of the survey to their members. A special thank you to all the survey respondents for their time and effort in completing the survey and sharing their opinions.

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Executive Summary

Although a significant amount of fatigue-related research has been conducted in a wide range of settings, fatigue remains a major contributor to workplace injuries and fatalities. Safety-critical workers in the transportation industry, specifically the rail industry (e.g., locomotive engineers and conductors) are particularly vulnerable to fatigue due to the nature of the work (e.g., shiftwork, night work, irregular schedules) and job demands (e.g., the need to sustain attention and long periods of low-demand activity) (Mollard et al., 1990; Sussman and Coplen, 2000). An assessment of the important factors contributing to fatigue and the effects of these factors on safety from the perspective of railroad workers is necessary to facilitate fatigue mitigation. The objective of this study was to better understand the factors that contribute to fatigue in locomotive engineers and conductors, and the potential impact on occupational safety.

An online survey sponsored by the Federal Railroad Administration, developed by the Virginia Tech Transportation Institute, and approved by the U.S. Office of Management and Budget, was distributed by the Brotherhood of Locomotive Engineers and Trainmen (BLET) and Sheet Metal Air, and Rail Transportation Workers – Transportation Division (SMART-TD) labor unions to their members. The project period was May 2018 to February 2023 and survey administration took place February 9, 2022, to April 9, 2022.

Completion of the survey was entirely voluntary, and no compensation was offered. All information collected was anonymous and confidential. The survey included 44 questions related to the frequency and impact of fatigue as well as contributors to fatigue, strategies to cope with fatigue, and any associated fatigue-related workplace safety events. Researchers took a conservative approach to validate the data to ensure the robustness of the final dataset. Exclusion criteria included: incomplete survey; multiple survey submissions from the same IP address; not currently working as a locomotive engineer or conductor; and working on passenger trains (i.e., the focus was on freight). After data validation, the final dataset included 9,084 responses with an almost equal 50/50 split on job role (4,497 locomotive engineers and 4,587 conductors).

The survey showed that not only did locomotive engineers and conductors frequently experience fatigue, but it also indicated fatigue affected their operation of a locomotive train. Self-identified highly fatigued locomotive engineers and conductors were:

- Twice as likely to experience any type of fatigue-related safety event while operating a locomotive compared to those who were not highly fatigued
- Four times more likely to have missed a required stop compared to conductors not feeling highly fatigued
- 3.4 times more likely to have had a near miss while operating a locomotive than locomotive engineers who reported not feeling highly fatigued

Just under 40 percent of participating locomotive engineers and conductors fit the classification of being highly fatigued; over 60 percent of locomotive engineers and conductors were classified as not being highly fatigued.

Fatigue also increased the odds of locomotive engineers and conductors being involved in fatigue-related driving events during their commute to and from work. The risk was higher for those who reported having long commute times (i.e., over one hour). The major contributors to fatigue were related to scheduling, or lack thereof in the case of irregular work. Variability in start times and frequent switching from day to night work were associated with increased risk of fatigue for locomotive engineers and conductors. Shiftwork, long-duration tasks, and disturbances in the sleep-wake cycle are well-documented contributors to fatigue and key risk factors identified in this survey for safety incidents both in the workplace and on the roads.

1. Introduction

Freight railroads have 24-hour operations and shiftwork. Research has consistently shown that shiftwork can cause major disruptions in sleep and circadian rhythms in workers, which in turn results in reduced alertness and impaired performance, among other effects (Akerstedt et al., 1987; Lal and Craig, 2001).

1.1 Background

Fatigue is believed to be a significant problem in railroad operations, largely due to demanding labor, long duty periods, disruptions of circadian rhythms, and accumulative sleep debt. Multiple factors influence worker fatigue, including time awake, quality and quantity of sleep, time of day, and workload. Fatigue is hazardous in the workplace, as it can harm both the health and safety of the worker and those with whom they work. Although fatigue is a complex phenomenon, the term is widely used in occupational medicine. A general definition is "a state of feeling tired, weary, or sleepy that results from prolonged mental and physical work, extended periods of anxiety, exposure to harsh environments, or sleep loss" (Sadeghniiat-Haghighi and Yazdi, 2015). Fatigue can result from prolonged mental or physical exertion and can impair physical and mental performance and alertness. Distinguishing between task-related and sleep-related fatigue contextualizes the etiology of the condition; however, the presentation of symptoms is very similar. Task-related fatigue usually reflects the workload of the task being carried out, working hours, and shiftwork. Sleep-related fatigue is affected by sleep loss, poor quality sleep, and insufficient rest (Fan and Smith, 2018). Acute fatigue results from short-term sleep loss or short periods of heavy mental or physical work; in contrast, chronic fatigue is fatigue carried forward over days, weeks, or even months (Fan and Smith, 2018). Both acute and chronic fatigue are problematic for safety-critical work that requires vigilance and cognitive acuity.

1.1.1 Factors that Contribute to Workplace Fatigue

Multiple lifestyle, personal, and workplace factors combine to result in workplace fatigue. Sleep patterns and circadian factors, such as sleep quantity and quality, sleep timing, sleep environment, and time awake, influence sleepiness and fatigue (Humphries, 2009; Roehrs and Roth, 2001). Individual variability, such as personality characteristics (individual sleep needs) and demographics (marital/family status and culture), also influence fatigue (Khalafi, 2014). Lifestyle factors including sleep hygiene, exercise, and nutrition habits can impact energy and fatigue levels (Youngstedt and Kline, 2006; Golem et al., 2014). Workplace factors that influence fatigue include environmental factors, scheduling factors, and task characteristics (Khalafi, 2014). Environmental factors include temperature, noise, lighting, isolation, and commuting distances (Cajochen, 2007). Scheduling factors include duty and non-duty hours, irregular or unpredictable work hours, and shiftwork (Akerstedt et al., 2009). Task characteristics include features of work tasks, such as monotony, difficulty, duration, time-on-task, attention and vigilance, and workload (Dunn and Williamson, 2012; van der Hulst et al., 2001). Workload can be further grouped into physical and mental tasks. Physical workload refers to work tasks that are physical in nature and may involve repetitive movements, static loads, awkward postures and forceful exertions that initiate fatigue (Horrey et al., 2011). Mental workloads include tasks that are mentally fatiguing, including job demands and stress, irregular schedules or long work hours, relationships with coworkers, and worker autonomy.

Personal factors often influence workplace factors and vice versa to increase fatigue and exacerbate the cycle. Regardless of the causes, sleepiness and fatigue can influence job performance and directly affect workplace safety through errors, accidents, medical care, absenteeism, and turnover. Fatigue can indirectly affect workplaces through lost productivity, poor social relationships, lowered motivation, and reduced cognitive performance (Van Dongen and Hursh, 2010; Whitmire et al., 2009; DeArmond and Chen, 2009).

1.1.2 Impact of Fatigue on Performance

Fatigue can have negative consequences on many human performance factors that are important for everyday functions and tasks. Fatigue can influence mood and motivation, vigilance and reaction time, proprioception, and psychometric coordination. Fatigue can also result in impairment in cognitive function such as poor memory, judgement, concentration, and problems processing information (Sadeghniiat-Haghighi and Yazdi, 2015; Abd-Elfattah et al., 2015). Emotional disturbances including stress, anxiety, irritability, depression, and aggression, can be brought on or exacerbated by fatigue, all of which can impact both short- and long-term job performance (Orzel-Gryglewska, 2010; Lanier, 2003).

Research shows that these consequences have implications for safety-sensitive workplace environments, especially for shiftworkers who deal with abnormal sleep and work cycles that add an additional layer of complexity. A study of healthcare workers demonstrated that, in addition to reducing job performance, shiftwork and long work hours increased the risk for worker obesity, injuries, and a wide range of chronic diseases (Caruso, 2014). One estimate puts worker fatigue costs at more than $18 billion a year in absenteeism, diminished productivity, health care costs, accidents, and other occupational costs (Pasupathy and Barker, 2012).

Scholars have found that fatigued shiftworkers have played a role in some of the most serious and catastrophic occupational incidents (Sadeghniiat-Haghighi and Yazdi, 2015). The 1986 Chernobyl nuclear power accident occurred at 1:23 a.m. when operators ran the plant without safety precautions and without proper coordination or communication with safety personnel (Jaworowski, 2010). Twenty-eight workers died from radiation and thermal burns within months of the incident, and the accident was thought to be responsible for nearly 7,000 cases of thyroid cancer. The accident at Three Mile Island in Pennsylvania, the most significant accident in U.S. commercial nuclear power plant history, occurred in the early morning hours and was attributed to a combination of system and equipment failures, inadequate training, and human factors errors (Mitler et al., 1988). The Exxon Valdez oil spill of 1989 occurred around midnight when an oil tanker struck a reef off the coast of Alaska. Multiple factors were identified as contributing to the incident, one of which being the third mate failed to properly maneuver the vessel, possibly due to fatigue or excessive workload (Haycox, 2012). In summary, fatigue-related poor human performance led to human error and potential incidents or accidents.

1.1.3 Fatigue in the Rail Industry

Fatigue is a safety and operational concern that must be effectively managed in the rail industry, particularly in safety-critical train crew roles, including locomotive engineers, signalmen, conductors, and dispatchers (Fan and Smith, 2018). Operating a train combines the need for prolonged and sustained attention with extended periods of low-demand activity interspersed with periods of high activity (Dunn and Williamson, 2012).

Signalmen supervise the automated traffic guidance; their tasks and responsibilities have fundamentally changed in recent years with automation (Brungger and Fischer, 2018). A frequent problem stated by signalmen is the rise of monotony during long and uneventful shifts. Conductors ensure the locomotive stays on schedule and follows safety rules and procedures to avoid incidents. They also deal with unexpected delays or emergencies (Fan and Smith, 2018).

Dispatchers are responsible for the safe and efficient movement of trains and other track users over a railroad and are often affected by high levels of workload, stress, and fatigue that can attenuate work performance (Popkin et al., 2001).

A 2013 Federal Railroad Administration (FRA) report examined the fatigue status of safety-critical railroad employees. The authors concluded exposure to fatigue elevated the risk of a human factors accident from 11 to 65 percent, and the economic cost of a human factors accident involving fatigue was 4 times the amount than in the absence of fatigue (approximately $1,600,000 compared to $400,000) (Gertler et al., 2013). Engineers, conductors, and dispatchers had the longest work hours, work at night, and had the highest exposure to fatigue. Passenger engineers and conductors had the least exposure to fatigue, explained by the predictability of passenger train and engine work schedules and less nighttime work.

Scheduling

Current statutory Hours of Service (HOS) regulations, enforced by FRA, limit on-duty hours for train and engine employees, signal employees, and dispatching service employees (HOS law (49 U.S.C. § 21101)). Train service employees and signalmen may work no longer than 12 continuous hours followed by a minimum of 10 hours off-duty (49 U.S.C. § 21103 and 21104). Locomotive engineers and conductors must be given at least 8 consecutive hours off-duty in every 24-hour period. The required 8 hours off-duty time includes commuting, leisure, and personal time, all of which may potentially reduce sleep time even more. Locomotive engineers, conductors, and signalmen may be allowed to remain on-duty for not more than 4 additional hours in any period of 24 consecutive hours when an emergency exists. Further, work periods that include traveling to a work site, waiting on a train, and traveling back to the point of final release can exceed 12 hours but are not considered part of the 12-hour work period. Dispatchers follow slightly different HOS regulations (49 U.S.C. § 21105). When at least two shifts are employed, dispatching service employees may work 9 hours during a 24-hour period; when only one shift is employed, dispatching service employees may work 12 hours in a 24-hour period. During an emergency, dispatching service employees may work 4 additional hours in a 24-hour period, but not exceeding 3 days during a period of 7 consecutive days.

Unique features of the rail industry in terms of hours of service are deadheading and limbo time. "Deadheading" refers to moving a crew from one point to another or to a train by vehicle transportation or by train. The time spent awaiting the arrival of a deadhead vehicle for transportation from the final duty assignment or to the point of final release is termed "limbo time." Time spent in deadhead transportation to a duty assignment is considered on-duty time, yet time spent in deadhead transportation from the final duty assignment to the point of final release is considered neither on- nor off-duty (Gertler et al., 2013). Therefore, the period of deadhead transportation to point of final release may not be included in the required 8- or 10-hour off-duty period. HOS regulations outline specific requirements for limbo time to limit the time employees spend waiting for deadhead transportation or in deadhead transportation from a duty assignment to the place of final release (49 U.S.C. § 21103). Deadheading and limbo time can compromise and delay the start of the rest period by adding time that is considered neither on-duty nor a rest period to the end of a shift (Gertler et al., 2013).

A 2011 final rule published by FRA implemented more stringent HOS regulations for passenger and commuter train conductors and engineers (49 CFR 228.1(d)). The rule limits the number of days of consecutive work for employees working overnight assignments. More rigorous regulations for shifts between 8 p.m. and 4 a.m. and limitations on time-on-duty in a single tour as well as consecutive duty tours or total duty are addressed with this rule.

Risk Factors for Fatigue in Rail Workers

Fatigue and its impact on safety-critical performance have been suggested as key issues in the rail industry; however, a systematic scientific study to determine levels of rail worker fatigue and the associated risk factors does not yet exist (Bowler and Gibbon, 2015). Other research shows that risk factors inherent in the rail industry that contribute to fatigue include long working times, heavy workload, shiftwork, and poor working environments (Pollard, 1990). Job-related stressors that contribute to fatigue include long commute times, uncertainty and unpredictability of on-call jobs, and conflicts with other job roles. A review of research on fatigue in operators working on road, sea, and rail concluded that, in the rail industry especially, poor work-life balance and absenteeism due to sickness were considered common outcomes of fatigue (Phillips, 2014). Reviews of British rail incidents confirmed fatigue was a cause in approximately 21 percent of high-risk railway incidents, negative work-life balance, insufficient sleep, shift pattern design, and work duration were primary causes of the fatigue (Gibson et al., 2015, 2016). Morgan et al. supported these findings in a study of rail workers' perceptions of accident risk factors, demonstrating the impact of these factors on stress and fatigue (Morgan et al., 2016). The authors also found fatigue and job demands impaired decision-making and risk management abilities, increasing risks for error, accidents, and incidents (Dorrian et al., 2007).

A recent literature review examined the impact of risk factors, including working hours, workload, shiftwork, job type and environment, sleep and rest, and lifestyle and other factors, on rail worker fatigue (Fan et al., 2018). The literature supports the notion that train operators and dispatchers working longer hours had higher fatigue scores than those working shorter shifts, regardless of train type (i.e., passenger or freight). Despite operating with a significant sleep debt, train operators were able to sustain vigilance while driving. One study surmised a possible explanation for this is that train operators on long trips usually have longer rest periods between the out and return trip, which could compensate for long work hours (Darwent et al., 2008; Kazemi et al., 2016). Positive associations were observed between workload and fatigue in train operators, engineers, and train crew members, while high workload and high levels of fatigue were also shown to increase mental health complaints, performance disengagement, and accident risk (Tsao et al., 2017; Fan and Smith, 2017; Zoer et al., 2011; De Luca et al., 2009). The literature shows night shifts resulted in fatigue, sleepiness, and cumulative sleep loss and fatigue develops more quickly during night shifts compared to day and evening shifts (Dorrian et al., 2011; Cotrim et al, 2017; Popkin et al., 2001). Harma and colleagues (2002) concluded that severe sleepiness at work was very common among both night and early morning shiftworkers. In train engineers specifically, fatigue was shown to cause them to disengage from work (Roach et al., 2001). Engineering crews generally work a higher percentage of night shifts due to the nature of their position (i.e., train maintenance and rail repair work scheduled at night to avoid daytime traffic and interference); therefore, fatigue may be especially important to consider for this subset of workers (Dorrian et al., 2011). Lifestyle and individual factors were also shown to impact fatigue in rail workers. Rail workers with unhealthy lifestyle behaviors, including smoking and drinking, as well as those with negative personality types were more likely to report high fatigue (Fan and Smith, 2017). Workers with heavier emotional and mental workloads and those lacking social support were also associated with fatigue and poor health (Zoer et al., 2011). Sleep deprivation associated with shiftwork resulted in fatigue and sleepiness at work but napping before starting shiftwork was shown to help workers cope with fatigue (Cabon et al., 2012; Darwent et al., 2015).

Operator fatigue has been determined as a contributing factor in high-profile, catastrophic railroad accidents. Between 2000 and 2020, the NTSB conducted 11 major investigations of accidents involving railroads in which fatigue was identified as the probable or a contributing cause of the accident.

For example, the Southwestern Railroad collision involved a freight train with 9 locomotives and 79 cars colliding with a standing freight train in the early morning hours of April 28, 2015 (NTSB Railroad Accident Brief). Nine locomotives derailed from the striking train and two locomotives, and three empty hopper cars derailed from the standing train. The conductor and the engineer on the lead locomotive of the striking train jumped before impact; the engineer died, and the conductor was hospitalized with serious injuries. Estimated damages totaled over $2 million. The engineer of the standing train had been awake for about 22 hours and the conductor nearly 9 hours before leaving the site of the accident; both had been on-duty for 7 hours at the time of the accident. The engineer and conductor of the striking train had each been on duty for nearly 10 hours at the time of the accident. The conductor said he was tired while driving away from the work site but had no difficulty staying awake during his shift. Accident investigators identified the conductor as committing an error of omission, along with indications he felt fatigued after his work shift. The conductor's failure to realign the switch and subsequent misinterpretation of his own work is consistent with fatigue-induced behavior. The National Transportation Safety Board (NTSB) determined the probable cause of the crash was the conductor of the train failing to return the switch for main track movement due to fatigue. A contributing factor was failure by the striking train crew to perceive the misaligned switch in non-signaled territory in time to avoid the collision.

1.1.4 Impact of Commute Time on Fatigue and Safety

Commuting can have a major effect on sleep, job performance, and safety. For workers who work extended shifts, long commutes that extend their workday even further can pose serious concerns. Long commutes mean lost personal and/or sleep time which can leave workers fatigued and ill-prepared for work, putting them at greater risk for accidents at work or on the road. The average commute time for U.S. workers to get to and from work is 25 minutes each way (McKenzie and Rapino, 2011). For a worker going to work 5 days a week, over 4 hours of their week is spent commuting. The implications of commuting on sleep loss were quantified by Hirsch-Allen and colleagues (2014), concluding that every minute of commute time equals 0.84 minutes of lost sleep. In many industries, job sites are far from home. For workers who drive their own vehicle to work, this extends time-on-task which can impact fatigue (Rosa et al., 1989). Commute time may also contribute to accumulating sleep debt, making it difficult to achieve a healthy amount of sleep (Evans et al., 1999).

Literature regarding commute times and their impact on fatigue for rail workers is limited. Maximum work hours and minimum rest periods for the U.S. railroad industry are federally regulated; however, these regulations do not restrict commuting distances without compensatory time off (Coplen and Sussman, 2000). Pollard (1990) interviewed train operators to examine the risk factors of different work patterns that contribute to fatigue. In addition to the main causes of fatigue, including long working times, heavy workload, shiftwork, and poor working environments, long commute times was identified as a potential stressor that causes fatigue. Gertler and Viale (2006) examined the work and rest schedules and sleep patterns of U.S. railroad maintenance of way (MOW) employees to investigate relationships between schedules and levels of alertness. The authors found several work characteristics, including total hours worked and commute time, were related to daytime alertness. MOW workers have a very different work environment and scheduling demands compared to train crew personnel, so these factors should be considered when making comparisons.

To improve the quality and quantity of available data relating to fatigue-related rail accidents, the U.K. Rail Safety and Standards Board (RSSB) reported on the role of fatigue in rail incidents (Bowler and Gibbon, 2015). Available data from the Incident Factor Classification System and the Safety Management Information System (SMIS) were analyzed to understand how fatigue contributed to 246 high-risk rail incidents, as well as to gain a sense of how often data was recorded into fields that may help identify fatigue and assist with mitigating risks presented by fatigue. The SMIS is the rail industry's national database for recording safety-related events that occur on the British rail network. The purpose of the SMIS is to collect safety-related data for analyses to assist the industry in analyzing risk, predicting trends, and focusing on major areas of concern for safety. All operating companies enter events manually into the SMIS; however, data entry by many different parties can result in inconsistent reporting. A major finding cited in the Bowler and Gibbon report (2015) was that relevant but optional fields for fatigue were often not completed in the SMIS, specifically information regarding work patterns, sleep duration, and worker commute times. The authors recommended making completion of these fields mandatory so that analyses of complete data sets are possible. A result of this report was that a long-term action plan to make these fields mandatory was agreed upon by the industry and the RSSB's System Safety Team would develop proposals for consultation.

Successful strategies to mitigate fatigue in rail operations depends on addressing many issues, one being commute time. Due to the considerable number of train crew staff who commute to and from work, commute time is a significant issue that should be considered.

1.1.5 Strategies for Combating Fatigue

Scheduling Tools

An effective, proactive fatigue risk management program in 24/7 operations should balance the amount of work performed against when the work is performed and how long a work schedule is in effect, among other variables. The Fatigue Avoidance Scheduling Tool (FAST) is a validated and calibrated bio-mathematical model that can assess the risk of fatigue in work schedules and plan schedules to mitigate fatigue and human factors accidents (Hursh et al., 2006). FAST considers the time of day when work occurs, circadian rhythms, and opportunities for sleep based on work schedules. It uses work histories prior to accidents and at the time of the accidents to calculate cognitive effectiveness, which is considered the inverse of fatigue. FAST calculates an effectiveness score associated with human factors accident risk. At an effectiveness score below 90, there is an elevated risk of a human factors accident. Effectiveness scores below 70 are associated with a 21 percent increase in a human factors accident; this is equivalent to performance decrements associated with a blood alcohol concentration of 0.08 or being awake for 21 hours following an 8-hour sleep period. An effectiveness score of 50 or less is associated with a 65 percent increase in human factors accident risk (Hursh et al., 2006).

The U.K. Health and Safety Executive (HSE) has its own fatigue prediction tool, the Fatigue and Risk Index, designed primarily to assess and compare the risks from fatigue associated with rotating shift patterns (HSE, 2006). This tool can also be used to identify a particular shift, within a schedule, that may be of concern for fatigue. A fatigue index and risk index is calculated based on factors including cumulative fatigue, workload, alertness, shift length, time of day, commute time, frequency and length of breaks, and recovery from a sequence of shifts. Individual differences and demographics, job role, and specific work-related issues are not considered in these calculations.

Another tool, the Alertness Consideration Tool (ACT), enables employees to consider fatigue risk when assessing fitness for duty (Energy Institute, 2014). The ACT can also assist in incident investigations or to provide a structured framework for discussions between a supervisor and an employee who has reported being fatigued. Originally developed by the Civil Aviation Safety Authority, the Energy Institute suggested it could be amended to fit the energy industry and other high-risk occupations (Energy Institute, 2014). The ACT assessment involves answering four questions about alertness, sleep, duty timing, and duty risk. Based on these responses, the employee can determine whether a fatigue risk may be present during their shift and take steps to manage the risk.

Fatigue modeling is also used to help establish work scheduling to stay below exposure thresholds to reduce risk of a fatigue related accident. Currently, FRA analyzes work schedules of accident-involved personnel during its accident investigations. Schedules are analyzed using a validated and calibrated biomathematical model of fatigue called the Fatigue Audit InterDyne, or FAID. Schedules include the previous 10 days prior to the accident or incident (if available); schedules of fewer than 10 days can be analyzed if a 10-day work history is unavailable. Investigators will still need to establish at least a 24–72-hour background on involved personnel for specific work/rest activity.

A significant amount of fatigue-related research has been conducted; however, fatigue remains a major contributor to workplace injuries and fatalities. Safety-critical workers in the transportation industry, such as locomotive engineers and conductors, are particularly vulnerable to fatigue due to the nature of the work (e.g., shiftwork, night work, rotating or irregular schedules) and job demands (e.g., need to sustain attention and long periods of low-demand activity) (Mollard et al., 1990; Sussman and Coplen, 2000). Thus, it is critical to understand the factors that contribute to operator fatigue by assessing their opinions and experiences. Of particular interest are the effects of commute time on fatigue and safety, which remain largely unexplored in the rail industry. Oftentimes, disconnects exist between the opinions and experiences of front-line workers and management personnel, particularly when it comes to the impact of fatigue (Camden et al., 2014).

1.2 Objectives

The goal of this study was to develop an in-depth understanding of the effects of commute time on locomotive crew fatigue and the resulting impact on safety. The objectives of this research were accomplished by assessing the opinions and perceptions of locomotive engineers and conductors via an online survey. This information is a critical step in developing effective fatigue-mitigation strategies and may also inform decision making, specifically for locomotive engineers and conductors.

1.3 Overall Approach

The survey used in this study was developed in 2019 to learn more about freight rail locomotive engineer and conductor commute times and the possible role it plays in fatigue prior to the labor issues associated with paid sick leave and attendance policies that have come to the fore in more recent years. While the survey does not address these important issues in that context, several the survey questions relate to scheduling variability and the unpredictable/irregular nature of the work.

1.4 Scope

The research described in this report used survey data collected from currently active locomotive engineers and conductors in the U.S. This information provided insight into the issue of fatigue in the railroad industry.

1.5 Organization of the Report

Section 2 discusses the methods used in this research. Section 3 discusses the research results. Section 4 presents a discussion of the survey and its limitations. Section 5 presents the research conclusions. The survey used in this research and announcements about the survey are presented in Appendix A.

2. Methods

An online survey sponsored by FRA and developed by the Virginia Tech Transportation Institute was distributed by the Brotherhood of Locomotive Engineers and Trainmen (BLET) and Sheet Metal Air, and Rail Transportation Workers – Transportation Division (SMART-TD) labor unions to their members. The purpose of the voluntary survey was to better understand the role of commute time and the factors that contribute to fatigue in locomotive engineers and conductors.

2.1 Survey Development

This was an exploratory project using a self-report survey designed to uncover information about a variety of fatigue-related factors. The survey was developed using previous questionnaires designed to investigate fatigue in various operational settings (e.g., Camden et al., 2014; Dunn, 2011; Williamson et al., 2001; Friswell et al., 2006). Camden and colleagues (2014) used a web-based questionnaire to investigate fatigue in winter maintenance operations (e.g., snowplow operators). Williamson et al. (2001) distributed pencil and paper questionnaires to long-haul truck drivers at truck stops in various locations in Australia to understand the factors that contribute to fatigue in long-distance heavy vehicle drivers. Friswell and colleagues (2006) focused on fatigue and occupational health and safety in the light- and short-haul transport sector in Australia. A survey by Dunn (2011) investigated the experiences of fatigue and monotony among locomotive engineers, both passenger and freight, in Australia. Thus, many of the questions included in the survey had been used on several different populations of interest in the past, all of whom would be considered safety-critical workers in the transportation industry. The survey was developed in close consultation with the two largest railroad operating unions in North America (i.e., BLET and SMART-TD), who represent more than 150,000 rail workers, including almost 70,000 locomotive engineers and conductors.

The US Office of Management and Budget (OMB) approved administration of the survey after FRA's completion of Paperwork Reduction Act requirements which included public notification and OMB review of the survey's methodology, sampling methods, and survey materials[1].

The survey was designed to be completed online and was anonymous. Anonymous surveys are a particularly effective method of investigating workplace fatigue in any industry because workers feel more comfortable expressing their true opinions, experiences, and beliefs. Respondents face no risk of repercussions from management as the surveys are anonymous and confidential, and the results are only reported in aggregate (i.e., not individually). Each union announced the survey on their respective websites and provided a link that took participants directly to the survey, administered using the online tool Qualtrics to perform data collection. The survey comprised 44 questions; responses were in the form of check boxes, multiple choice, and fill-in-the-blank. Completed surveys were automatically entered into a secure online database. Appendix A provides screenshots of the website announcements and the survey.

[1] https://omb.report/icr/201905-2130-001

2.2 Data Validation

A total of 9,084 surveys were validated. A conservative approach was taken when validating the data to ensure robustness of the final dataset. Data were excluded based on the following exclusion criteria:

- Respondent did not fully complete the survey (i.e., did not press "submit" at the end)
  - Excluded 3,334 responses
- Multiple survey submissions from the same IP address (i.e., only the first valid submission was accepted)
  - Excluded 528 responses
- Not currently working as a locomotive engineer or conductor
  - Excluded 212 responses
- Those working on passenger trains (i.e., for this analysis the focus was on freight)
  - Excluded 371 responses

For clarity, there was no auto submit button for the surveys. Completed surveys were submitted by respondents using a "submit" button. Incomplete surveys were not counted.

2.3 Analysis Approach

Analysis of the survey data was stratified by job role (i.e., conductor or locomotive engineer). Many survey questions were summarized using descriptive statistics and plots to illustrate the response distribution and visually compare the survey response for differences by job role. The two job roles were compared for differences in demographics (e.g., gender, age) using chi-square tests of independence. The chi-square test is a useful tool in assessing whether the distribution of one categorical variable significantly differs across another categorical variable. For example, the test would assess whether the proportion of survey respondents that are female is different for conductor respondents and locomotive respondents.

2.3.1 The Operational Fatigue Exhaustion Recovery (OFER) Scale

The inter-shift recovery (IR) subscale from the OFER scale was part of the survey and includes five statements that address the issue of recovery between shifts both directly and indirectly (Table 1). Scoring was either positively or negatively keyed depending on the statement. The total OFER-IR subscale score was determined by adding the individual responses to each of the five statements. Responses to each statement were assigned numerical values, from 1 to 7, with a 1 given to the lowest response option and a 7 given to the highest response option. Note for these statements there was an inverse relationship between fatigue and recovery with a low score indicating low fatigue but high recovery, and a high score indicating high fatigue but low recovery. A total score of 35 corresponds to the highest level of fatigue and lowest recovery for each statement.

Table 1. Statements and scoring for the OFER-IR subscale

Number	OFER-IR Statement	Scoring Method for Each Statement
1	I'm often still feeling fatigued from one shift by the time I start the next one	Strongly Disagree = 1 Strongly Agree = 7
2	I never have enough time between work shifts to recover my energy completely	Strongly Disagree = 1 Strongly Agree = 7
3	Even if I'm tired from one shift, I'm usually refreshed by the start of the next shift	Strongly Disagree = 7 Strongly Agree = 1
4	I rarely recover my energy fully between work shifts	Strongly Disagree = 1 Strongly Agree = 7
5	Recovering from work fatigue between work shifts isn't a problem for me	Strongly Disagree = 7 Strongly Agree = 1

2.3.2 Ranking Strategies to Manage Fatigue

Locomotive engineers and conductors were asked to report the use of various strategies to cope with fatigue during operation of a locomotive and to provide feedback on how effective these strategies were at mitigating fatigue. Strategy use was reported on a scale of each "always," "often," "sometimes," "rarely," and "never" and scored by the frequency of each of these response options (i.e., "always" given a higher rank than "never") to determine which strategies were used most frequently. Respondents also reported the effectiveness of the strategy for mitigating fatigue on a scale of "never effective," "slightly effective," "somewhat effective," "effective," and "very effective." These responses were then ranked accordingly with "very effective" given the highest rank and "never effective" given the lowest rank.

2.3.3 Assessing Highly Fatigued Locomotive Engineers and Conductors

A subset of highly fatigued operators was further assessed to understand potential contributors to fatigue. Highly fatigued locomotive engineers and conductors were defined as those who experienced fatigue *every tour of duty* or *on most tours of duty* and reported feeling too tired to drive home after work after *every tour of duty* or *several times a week*. Statistical models of highly fatigued locomotive engineers and conductors investigated 1) how high fatigue changes across operator work and scheduling factors and 2) how risk of involvement in safety-related events changes for highly fatigued operators.

To address the first investigation, logistic regression models predicted fatigue status (i.e., highly fatigued or not highly fatigued) by individual work and schedule factors. The work and schedule factors included workday schedule regularity (e.g., majority day work, majority night work, regular rotation of day/night, irregular rotation of day/night), start time regularity, and frequency of weekly day to night schedule changes. The models were controlled for age and gender.

Assume:

- operator Y_i is a binary random variable, such that $Y_i = \begin{cases} 1 & Highly\ Fatigued \\ 0 & Not\ Highly\ Fatigued \end{cases}, i = 1, 2, \ldots I$, where I iAs the total number of operators and

- Y_i follows a Bernoulli distribution where the probability of being highly fatigued is p_i.

The models were structured as follows:

$$\ln\left(\frac{p_i}{1-p_i}\right) = X_i'\beta$$

Where:

- $\ln\left(\frac{p_i}{1-p_i}\right)$ is the logit function,
- β is the vector of coefficients (including for workplace factor predictors, age, and gender), and
- X_i' is vector of predictor variables.

The analysis was performed for conductors and locomotive engineers, separately.

A common way to interpret the results of the logistic regression model is to calculate odds ratios (ORs) to understand how the odds of $Y_i = 1$ compare for values of the predictor variable. The OR is calculated by taking the exponential e of the predictor variable coefficient. The OR and its respective confidence interval (CI) calculation can often be easier to interpret compared to the model coefficients and model logit response variable. An OR that equals 1.0 (or a CI that contains 1.0) indicates there was no significant difference in the odds of being fatigued by the workplace factor levels. An OR greater than 1.0 (with CI bound also greater than 1.0) indicates the odds of being fatigued is significantly greater for one workplace factor level compared to the other level. An OR less than 1.0 (with CI bound also less than 1.0) indicates the odds of being fatigued is significantly lower for one workplace factor level compared to the other level.

ORs are helpful in analyzing the relationship between a categorical response variable (in this case, fatigued status) and response variables (like workplace factors). However, it is important to note a few limitations up front. Survey data does not directly determine a cause and effect; rather, surveys are incredibly useful tools in gathering sufficient data to understand how variables relate to each other. Also, the possibility exists that an extraneous variable not captured in the model and corresponding ORs may explain the response and predictor variables.

The second investigation explored how involvement in safety-related events changed with operator fatigue status using logistic regression models. Operators reported their involvement in safety-related events while operating a locomotive, including missed signal, crash, near miss, nodding off, missed stop, late braking, and going too fast, as well as fatigue-related driving events that occurred during their commute. The model explanatory or predictor variable was now fatigue status. Models controlled for age and gender.

Assume:

- operator Y_i is a binary random variable, such that for a specific safety-related event type $Y_i = \begin{cases} 1 & Reported\ involvement\ in\ safety-related\ event \\ 0 & Reported\ no\ involvement\ in\ safety-related\ event \end{cases}, i = 1, 2, \ldots I$, where I is the total number of operators and

- Y_i follows a Bernoulli distribution where the probability of being involved in the safety-related event is p_i.

The models were structured as follows:

$$\ln\left(\frac{p_i}{1-p_i}\right) = X_i'\beta$$

Where:

- $\ln\left(\frac{p_i}{1-p_i}\right)$ is the logit function,
- β is the vector of coefficients (including for high-fatigue status, age, and gender), and
- X_i' is vector of predictor variables.

The analysis was performed for conductors and locomotive engineers separately. For this investigation, an OR that equals 1.0 (or a CI that contains 1.0) indicates there was no significant difference in the risk of being involved in the safety-related event for highly fatigued operators compared to operators not highly fatigued. An OR greater than 1.0 (with CI bound also greater than 1.0) indicates highly fatigued operators had significantly greater risk of being involved in the safety-related event compared to operators not highly fatigued. An OR less than 1.0 (with CI bound also less than 1.0) indicates highly fatigued operators had significantly lower risk of being involved in the safety-related event compared to operators not highly fatigued.

3. Results

3.1 Participant Demographics

After data validation was complete, the final dataset comprised 9,084 responses with an almost equal 50/50 split on job role (Table 2). Most of the participants were males, with females making up just 2.5 percent of the survey respondents. A chi-square test of independence found the distribution of gender was significantly different between conductors and locomotive engineers ($\chi^2 = 4.2447$, $df = 1$, $p = 0.0394$), with significantly more female conductors than female locomotive engineers (2.86 vs. 2.18 percent, respectively).

Table 2. Frequency count and percent of total respondents by job role

Job Role	Frequency	Percent
Conductor	4,587	50.50
Locomotive engineer	4,497	49.50

Two-thirds of the respondents were between 35 and 54 years old, with most being 35–44 years old (36.67 percent). Few respondents were under 25 (1.17 percent) or over 65 years old (0.84 percent). Figure 1 shows the distribution of age by job role. A chi-square test of independence was statistically significant ($\chi^2 = 373.70$, $df = 5$, $p < 0.0001$), indicating a significant difference in the distribution of age between the job roles. Most conductors were 35–44 years old (38.10 percent) and the majority of locomotive engineers were 45–54 years old (37.48 percent). A greater proportion of conductors fell within the two youngest age categories (34 years or younger), while a greater proportion of locomotive engineers fell within the two oldest age categories (i.e., 55 years or older).

Figure 1. Percent of respondents by age category

Survey respondents reported experience both in their job role and in the rail industry. Any responses that showed more than 30 years of experience were manually reviewed for validity, considering the reported age. From the manual review, two respondents were removed from analysis, because they reported years of experience not possible given their reported age (e.g., respondent reports over 30 years of experience and an age of 35). These respondents reported industry and job role experience of at least 66 years. The average years of industry experience was 11.39 years (*SD* = 6.35) for conductors and 16.83 years (*SD* = 7.20) for locomotive engineers. The minimum reported industry experience was less than 1 year for both job roles, with a maximum of 47 years for conductors and 49 years for locomotive engineers. Years of experience were binned into categories. As shown in Figure 2, locomotive engineers had more industry experience than conductors with three-quarters of locomotive engineers having 11 or more years of experience compared to 45 percent of conductors reporting the same.

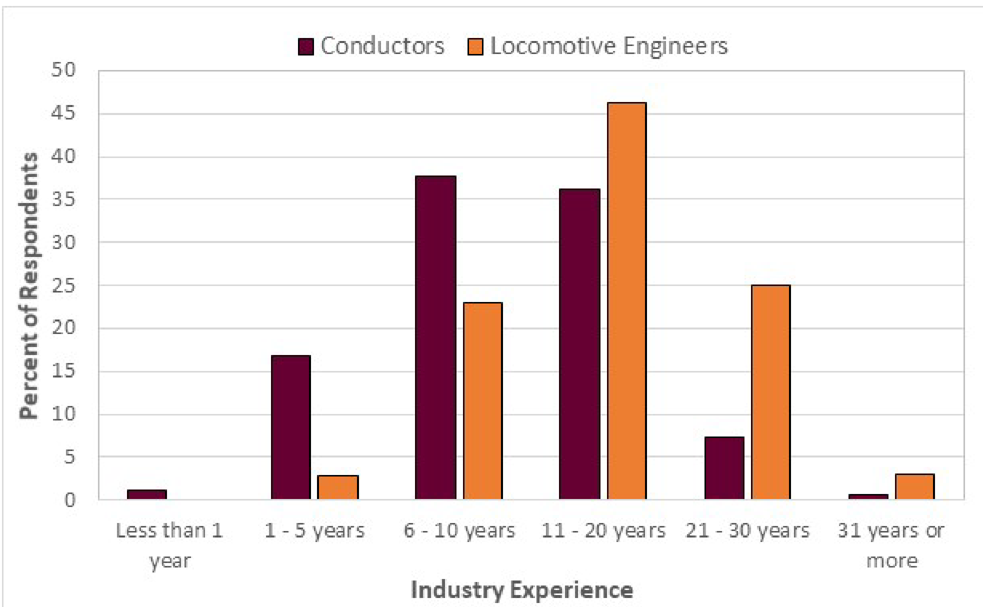

Figure 2. Percent of respondents by years of industry experience

Like industry experience, locomotive engineers had more years of experience in their job role than conductors (Figure 3). The average job role experience was 11.04 years (*SD* = 6.20) for conductors and 15.02 years (*SD* = 7.23) for locomotive engineers. Twenty-two percent of locomotive engineers reported more than 20 years of job role experience compared to 7 percent of conductors reporting the same.

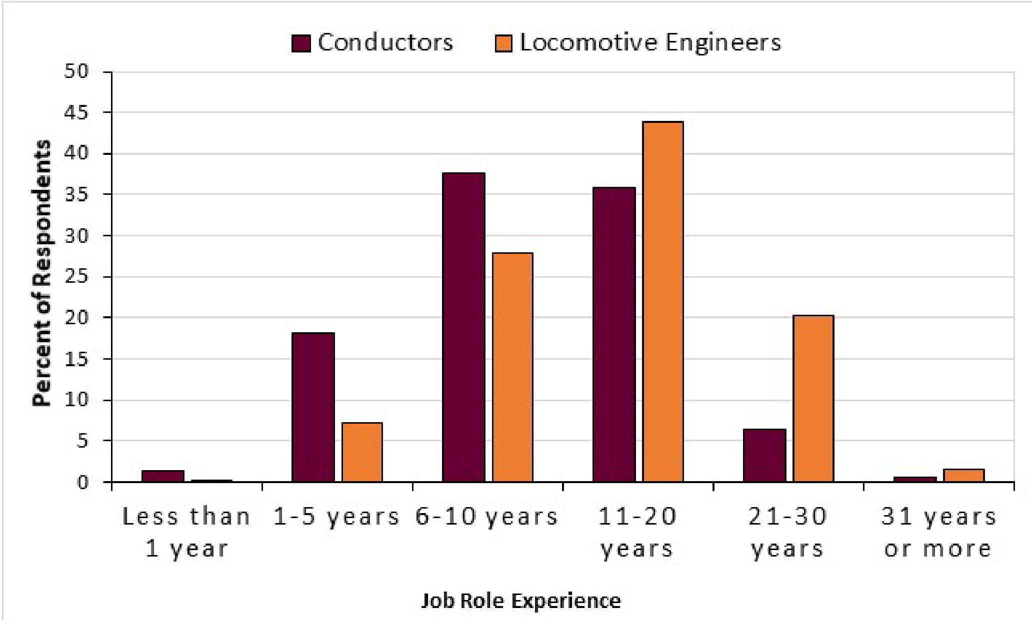

Figure 3. Distribution of job role experience by job roles

3.2 Variability in Scheduling

3.2.1 Start Time

As shown in Figure 4 and Figure 5, 60 percent of conductors and two-thirds of locomotive engineers reported day-to-day start time variation of 8 hours or more. For both job roles, more than 4 in 5 respondents reported varied day-to-day start times of at least 4 hours.

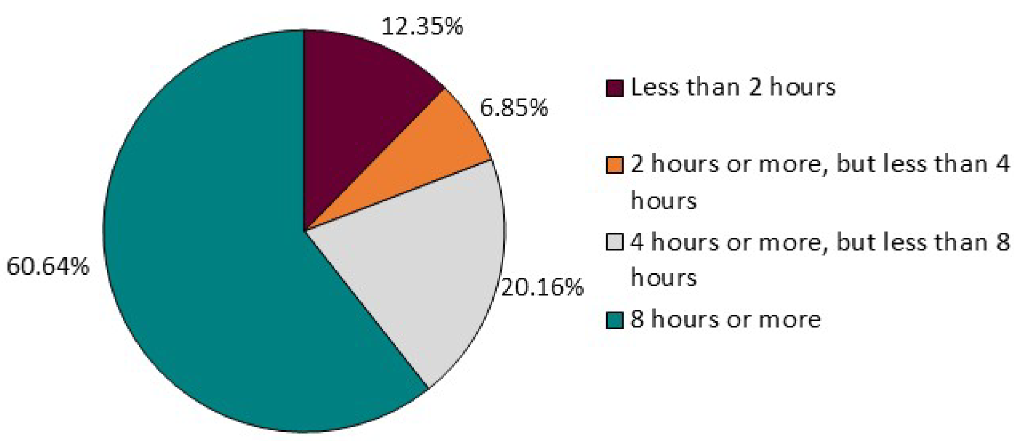

Figure 4. Percent of conductors with varied day-to-day start times

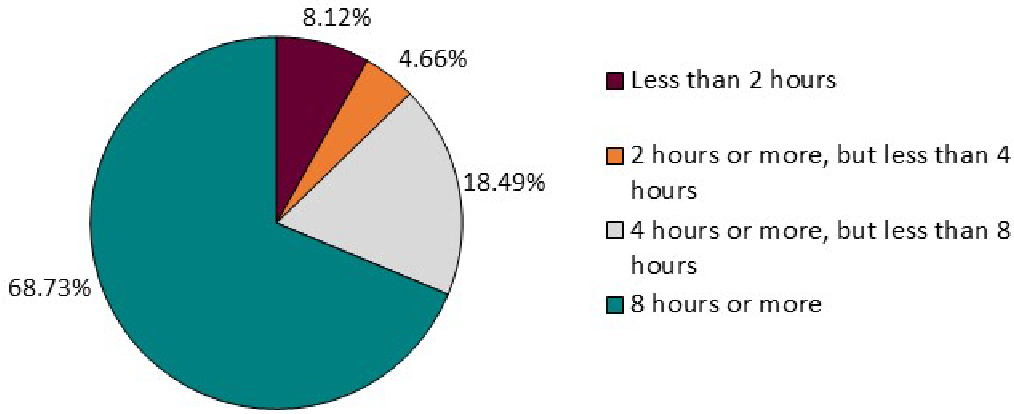

Figure 5. Percent of locomotive engineers with varied day-to-day start times

3.2.2 Day/Night Work Consistency per Week

Locomotive engineers and conductors were asked how many times per week their shifts changed from day work to night work and vice versa (Figure 6 and Figure 7). Nearly 90 percent of conductors and 92 percent of locomotive engineers reported two or more changes from day work to night work in a 1-week period.

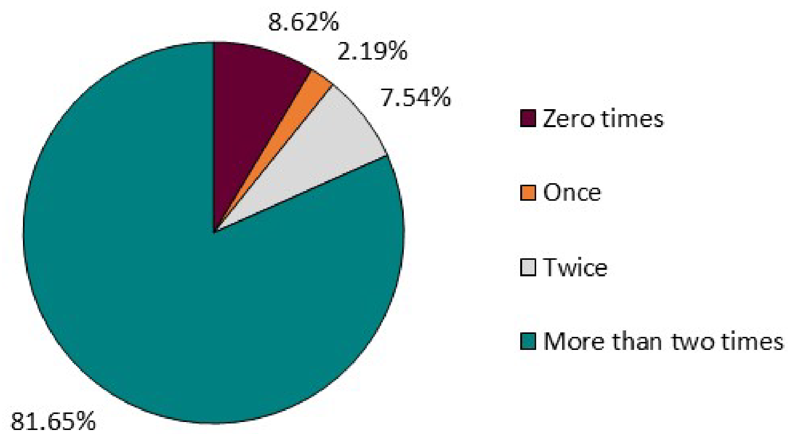

Figure 6. Percent of conductors by number of changes from day work to night work per week

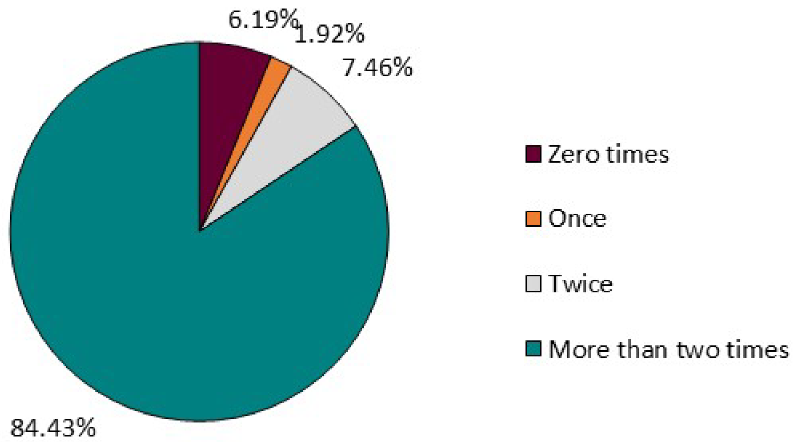

Figure 7. Percent of locomotive engineers by number of changes from day work to night work per week

3.2.3 Company-Provided Train Lineups

Most railroad operators provide schedules to locomotive engineers and conductors in the form of lineups that are accessed online. Company-provided lineups were reported by 92.17 percent of conductors and 93.04 percent of locomotive engineers (Table 3). Approximately 5 percent of conductors and locomotive engineers reported not receiving a lineup from their rail operator. The remaining responses were "not sure."

Table 3. Percent of respondents provided with a lineup

Company-Provided Lineups	% of Conductors *(n = 4,560)*	% of Locomotive Engineers *(n = 4,485)*
Yes	92.17	93.04
No	5.11	5.44
Not sure	2.72	1.52

Despite being provided with lineups, most conductors and locomotive engineers reported that the information contained in the lineup was somewhat or very unreliable (84 percent and 88 percent, respectively). Less than 1 percent of respondents indicated the information was very reliable (Figure 8).

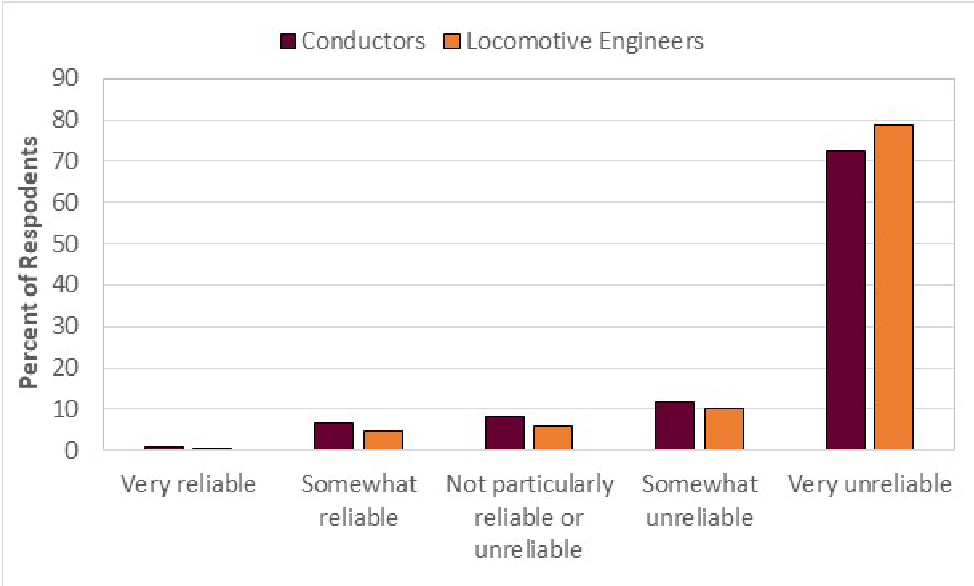

Figure 8. Percent of respondents by reliability of company-provided lineups

3.3 Commute Information

Nearly all conductors and locomotive engineers used their own car to commute to and from work (99.50 percent and 99.49 percent, respectively). The remaining 0.5 percent of respondents reported using car/van pool, motorcycle, public transportation, bicycle, walked, or "other" form of transportation (Table 4). Additionally, a follow-up question indicated that over 99 percent of respondents commuted to and from work alone.

Table 4. Percent of respondents by commute method

Commute Method	% of Conductors *(n = 4,587)*	% of Locomotive Engineers *(n = 4,497)*
Drive my own car	99.50	99.49
Car/van pool	0.31	0.18
Drive my own motorcycle	0.09	0.13
Public transportation (train, bus, etc.)	0.04	0.04
Ride a bicycle	0.00	0.02
Walk	0.07	0.07
Other	0.00	0.07

Most conductors and locomotive engineers indicated they commute to work 5 or 6 days a week, with an additional 12 percent commuting 7 days per week (Figure 9). Based on free response entries to this question, however, there were additional factors that affected commuting frequency. Responses showed that some conductors and locomotive engineers commute to work, then have a secondary location to stay close to work for multiple days, thereby reducing the number of days required to commute to and from work.

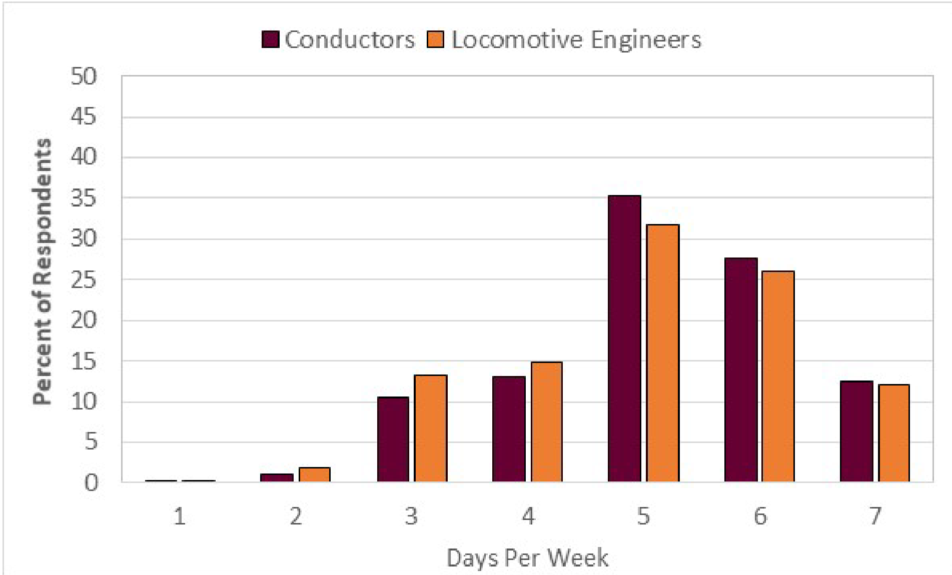

Figure 9. Percent of respondents by commuting days per week

Conductors and locomotive engineers were asked if they typically made stops or detours during their commute to or from work, such as child-care-related stops, shopping, or other errands. Most conductors and locomotive engineers reported not stopping during their commute; however, of those who reported stopping, more stops occurred on the way to work rather than on the way home (Table 5).

Table 5. Percent of respondents who reported stopping during their commute

Commute Direction	% of Conductors *(n = 4,580)*	% of Locomotive Engineers *(n = 4,487)*
To work	36.22	37.26
To home	30.76	28.23

Conductors and locomotive engineers reported average daily commute times to work and to home in the preceding month. Average commute times, shown in Figure 10, were slightly lower for locomotive engineers than conductors on both the commute to work and to home (40 mins vs. 42 mins, respectively). As shown by the error bars, there was a lot of variability in the responses, with some respondents noting they use multiple residences (e.g., one "home" location further from their workplace and an alternative residence closer to the workplace). Other respondents noted their commute time depended on the site to which they were asked to report, with some sites located several hours from their home. The average reflected in Figure 10 is the distribution of commute times for respondents who provided a single commute time value for to work and to home. If a respondent reported a range of less than 60 minutes (e.g., 30–45 mins), the average point of the range was used to represent their typical commute time. Due to the variability in the responses, the median may be a more preferred metric, as the median is unaffected by extreme outliers. The median commute time for locomotive engineers was 30 minutes each way, while conductors were slightly higher at 35 minutes each way.

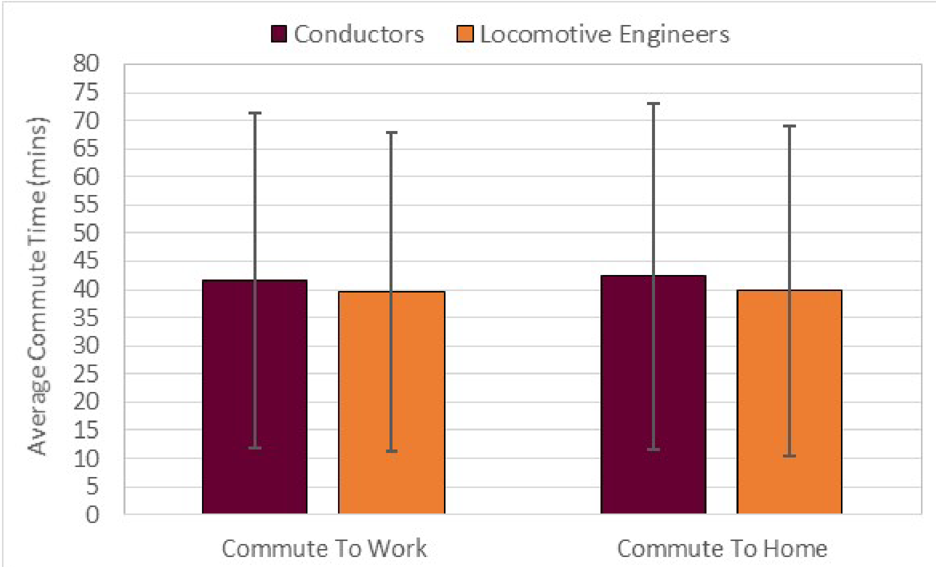

Figure 10. Average commute time to work and to home by job role

Commute times were then binned into categorical levels according to trip duration. Commute time categories were based on the distribution of the data with cutoffs roughly corresponding to the quartiles. This resulted in the following commute time duration categories: short (15 mins or less), medium (16 to 30 mins), long (31 to 60 mins), and extra-long (above 60 mins). As shown in Figure 11, roughly two-thirds of locomotive engineers and conductors had either a medium or long commute to work and to home. Slightly more locomotive engineers than conductors had a short commute (20 percent versus 17 percent), and less than 15 percent of respondents had an extra-long commute.

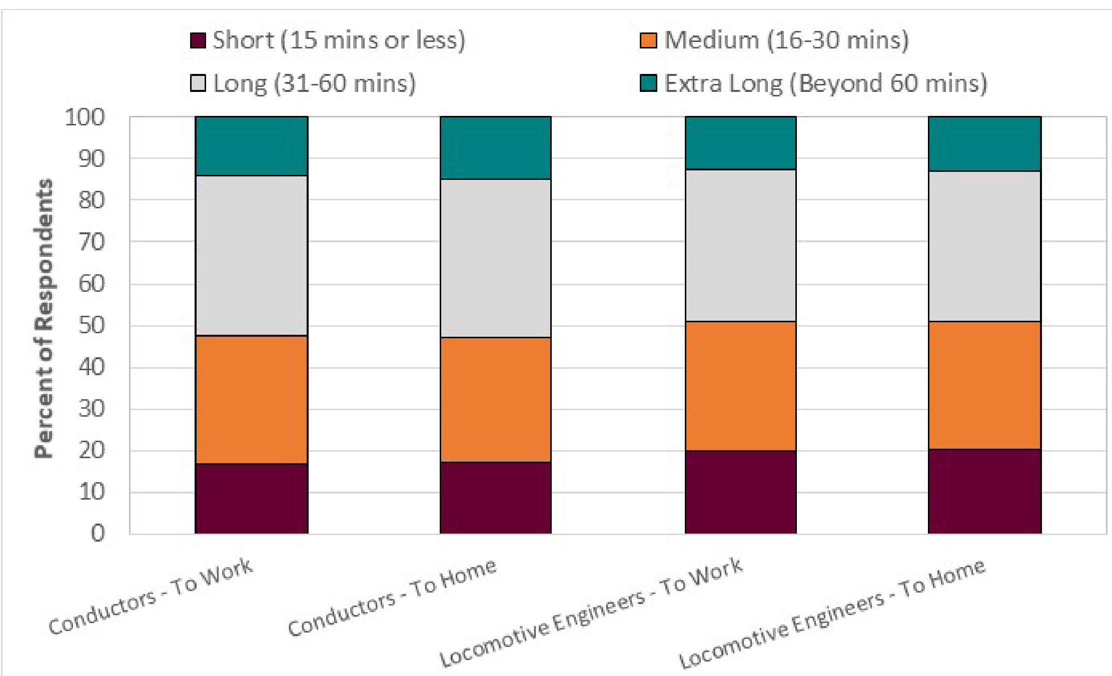

Figure 11. Percent of respondents by commute time duration category

To assess the impact of commute times on risk of involvement in a fatigue-related driving event, logistic regression models were used with a commute time duration category as a predictor. There were four commute time duration categories (i.e., short, medium, long, extra-long). These models resulted in a substantial number of comparisons, as each category was compared to the other three individual categories separately (e.g., short vs. medium, short vs. long, short vs. extra-long, medium vs. short, medium vs. long, etc.). Due to the large number of comparisons, the odds ratios presented below represent the comparisons of greatest potential interest — the odds of involvement in each fatigue-related driving event during an extra-long commute (> 60 mins) compared to a medium commute (15–30 mins) and during an extra-long commute compared to a short commute (< 15 mins).

Odds ratios were calculated for locomotive engineers and conductors, with an odds ratio greater than 1.0 indicating a significantly greater risk of being involved in a fatigue-related driving event during an extra-long commute compared to a medium or short commute. An odds ratio less than 1.0 would indicate a significantly lower risk of involvement in a fatigue-related driving event during an extra-long commute compared to either medium or short commute.

Figure 12 shows the impact commute times had on the likelihood of locomotive engineers and conductors experiencing various fatigue-related driving events. These results clearly demonstrate the detrimental impact of long commute times on driving performance, particularly commutes of more than 60 minutes. Locomotive engineers with an extra-long commute were 3 to 6 times more likely to experience a fatigue-related driving event than those with a short commute. Similarly, conductors were 3 to 9 times more likely to experience a fatigue-related driving event if they had a short commute compared to an extra-long commute.

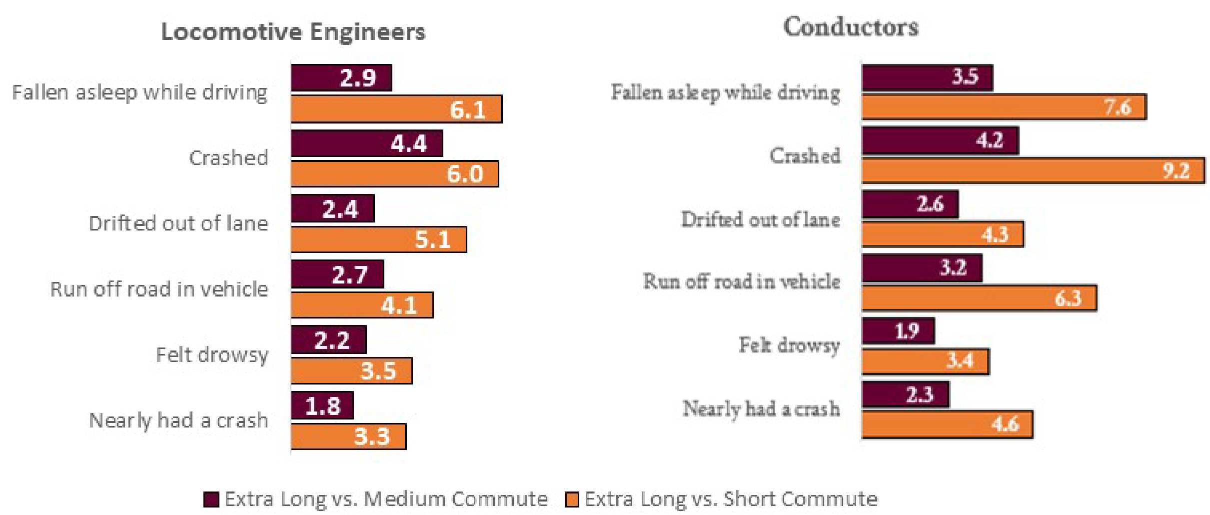

Figure 12. Odds of being involved in a fatigue-related driving event during an extra-long commute home compared to a medium or short commute

3.4 Occurrence of Fatigue and Fatigue-Related Behaviors

The survey included six statements based on items from the OFER scale. These statements required survey respondents to rate how strongly they agreed or disagreed with the statement. Additional analyses in this section included any experience with fatigue-related behaviors that occurred while commuting or operating a locomotive and the usage and effectiveness of various strategies to cope with fatigue.

3.4.1 OFER Scale

Six statements were included from the OFER scale, five of which formed the OFER-IR subscale and one that focused on acute fatigue and directly assessed post-work exhaustion. Responses to the acute fatigue statement were heavily skewed, with nearly 90 percent of conductors and locomotive engineers agreeing or strongly agreeing that they "usually feel exhausted when I get home from work," indicating the presence of a high level of self-reported acute fatigue. Less than 3 percent of respondents disagreed or strongly disagreed with this statement.

The five remaining OFER-IR statements showed similar, heavily skewed distributions of responses, depending on whether the statement was positively or negatively keyed. Overall, the responses to the OFER-IR statements indicated low levels of inter-shift recovery for both conductors and locomotive engineers. The main findings for the individual OFER-IR statements are summarized below:

- Approximately 75 percent of conductors and locomotive engineers agreed or strongly agreed that they "never have enough time between work shifts to recover my energy completely."
- Less than 3 percent of conductors and locomotive engineers agreed or strongly agreed that "even if I'm tired from one shift, I'm usually refreshed by the start of the next shift."
- Just over 75 percent of conductors and locomotive engineers agreed that they "rarely recover my energy fully between work shifts."
- Roughly 4 percent of conductors and locomotive engineers agreed or strongly agreed that "recovering from work fatigue between shifts isn't a problem for me."
- Over 76 percent of conductors and locomotive engineers agreed or strongly agreed that they are "often still feeling fatigued from one shift by the time I start the next one."

The total OFER-IR subscale score was determined by adding the individual responses to each of the five statements. Conductors and locomotive engineers with a score of 35 self-reported the highest level of fatigue and the lowest inter-shift recovery for each of the 5 statements. As shown in Figure 13, more than half of the conductors and locomotive engineers (i.e., 57 percent for both) reported scores over 30, meaning they gave the highest or second highest value (i.e., 7 or 6) to each statement. Approximately 1 in 4 conductors and locomotive engineers had a total score of 34 or 35 (26 and 24 percent, respectively). These results indicate that the levels of fatigue present in these workers outweigh the current opportunities provided for recovery from fatigue.

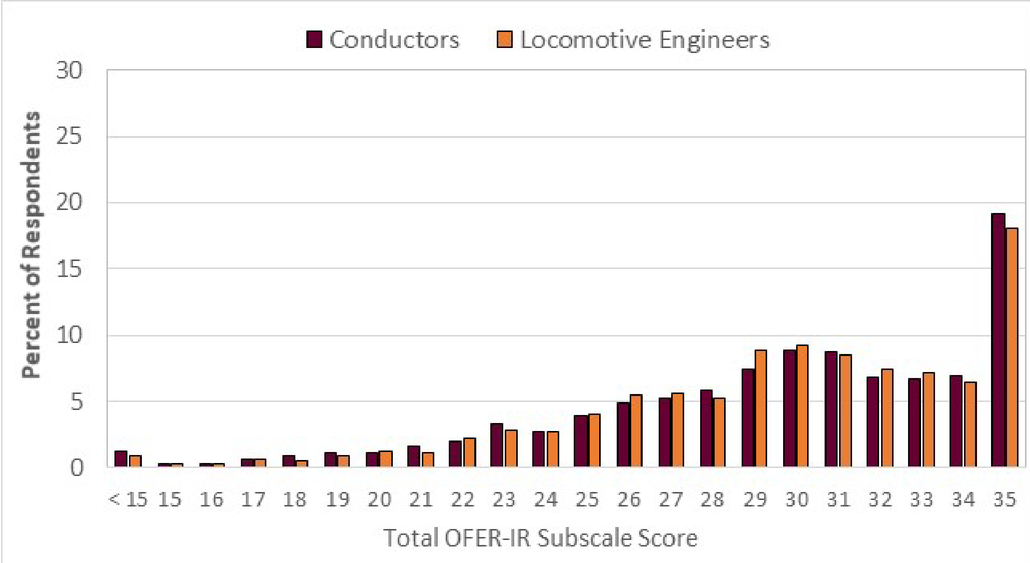

Figure 13. Distribution of the total OFER-IR subscale score

3.4.2 Fatigue-Related Driving Events during Commutes

Conductors and locomotive engineers indicated if they had experienced any fatigue-related driving events during their commute either to work or to home. As shown in Figure 14, conductors and locomotive engineers reported more fatigue-related driving events occurring during their commute home from work compared to their commute to work.

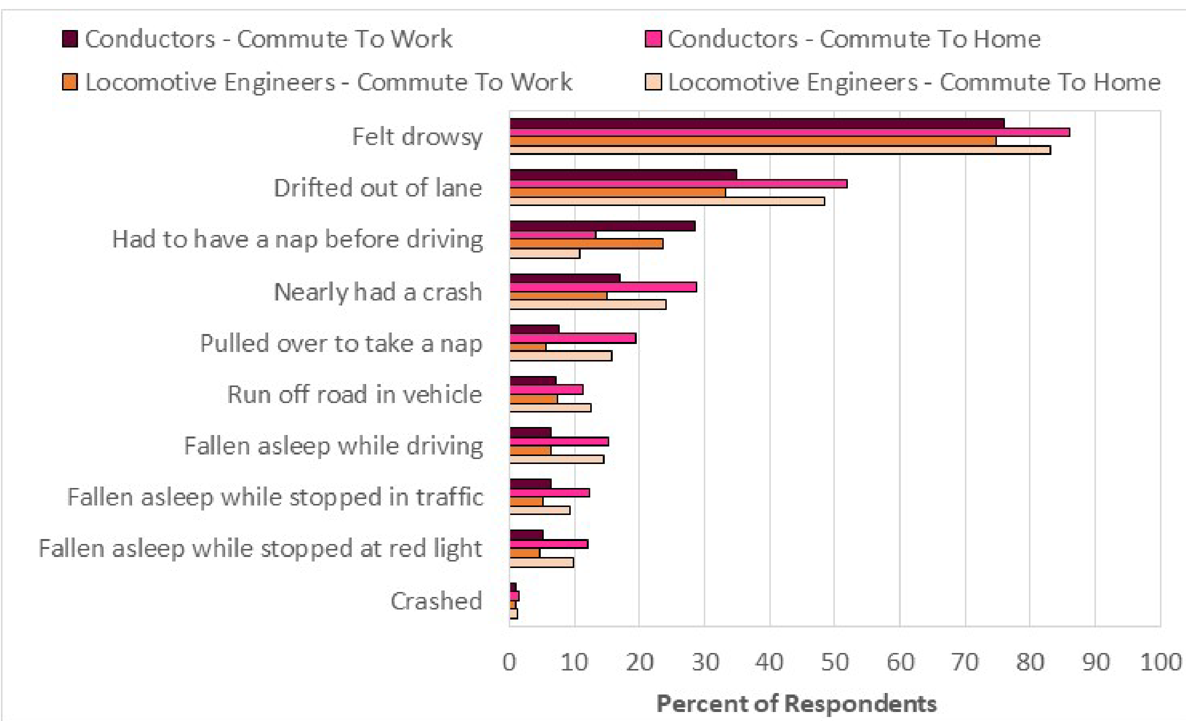

Figure 14. Percent of respondents who reported fatigue-related driving events during their commute to work and to home

Roughly half of both conductors and locomotive engineers reported they had drifted out of their lane during their commute home compared to a third of respondents reporting the same event occurring during their commute to work. Nearly 40 percent of conductors and 34 percent of locomotive engineers reported falling asleep either while driving, stopped in traffic, or stopped at a red light during their commute home from work. Around one in four conductors and locomotive engineers reported a fatigue-related near-crash on their way home from work

3.4.3 Impact of Fatigue in the Workplace

Less than 1 percent of conductors and locomotive engineers reported never feeling fatigued during train operation and less than 2 percent rarely felt fatigued (Figure 15). Most conductors and locomotive engineers reported feeling fatigued on most tours of duty (39.24 percent and 43.20 percent, respectively), while roughly 1 in 5 conductors and locomotive engineers reported feeling fatigued on every tour of duty (19.33 percent and 21.4 percent, respectively).

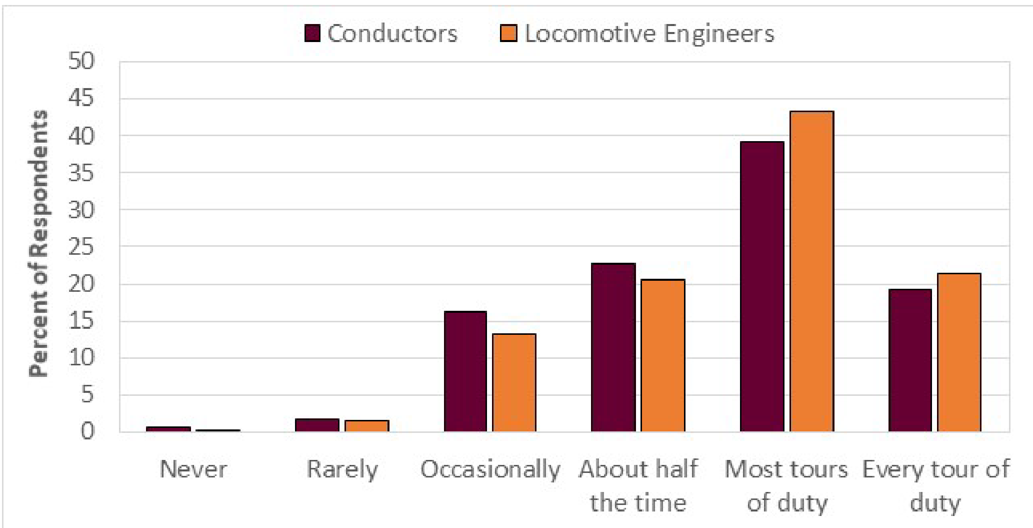

Figure 15. Frequency of fatigue during locomotive operation

Conductors and locomotive engineers reported to what degree they think fatigue affects their operation of the locomotive (Figure 16). Approximately half of conductors and locomotive engineers believe fatigue has a significant impact on their locomotive operation (51.69 percent and 47.34 percent, respectively), and just over one-third felt fatigue had a moderate impact (36.01 percent and 37.51 percent, respectively). Very few respondents reported that fatigue had no impact on their operation of the locomotive.

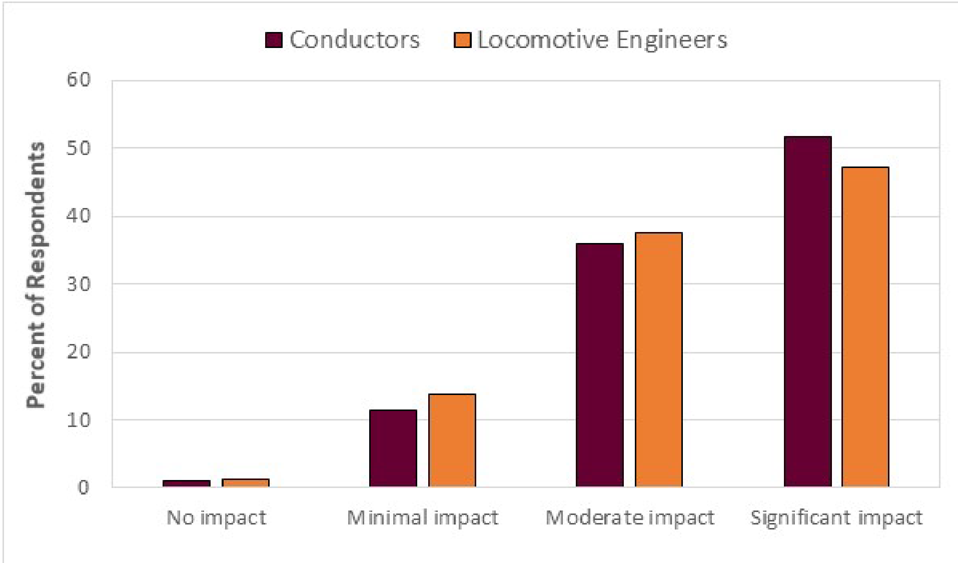

Figure 16. Percent of respondents by the degree to which fatigue impacts their operation of the locomotive

3.4.4 Factors Contributing to Workplace Fatigue

When asked what factors contributed most to their fatigue at work, conductors and locomotive engineers again had very similar responses (Figure 17), with the top five responses corresponding to well-known contributors to fatigue, such as irregular work (e.g., no set pattern), long hours, nightwork, and issues associated with sleep and time off work.

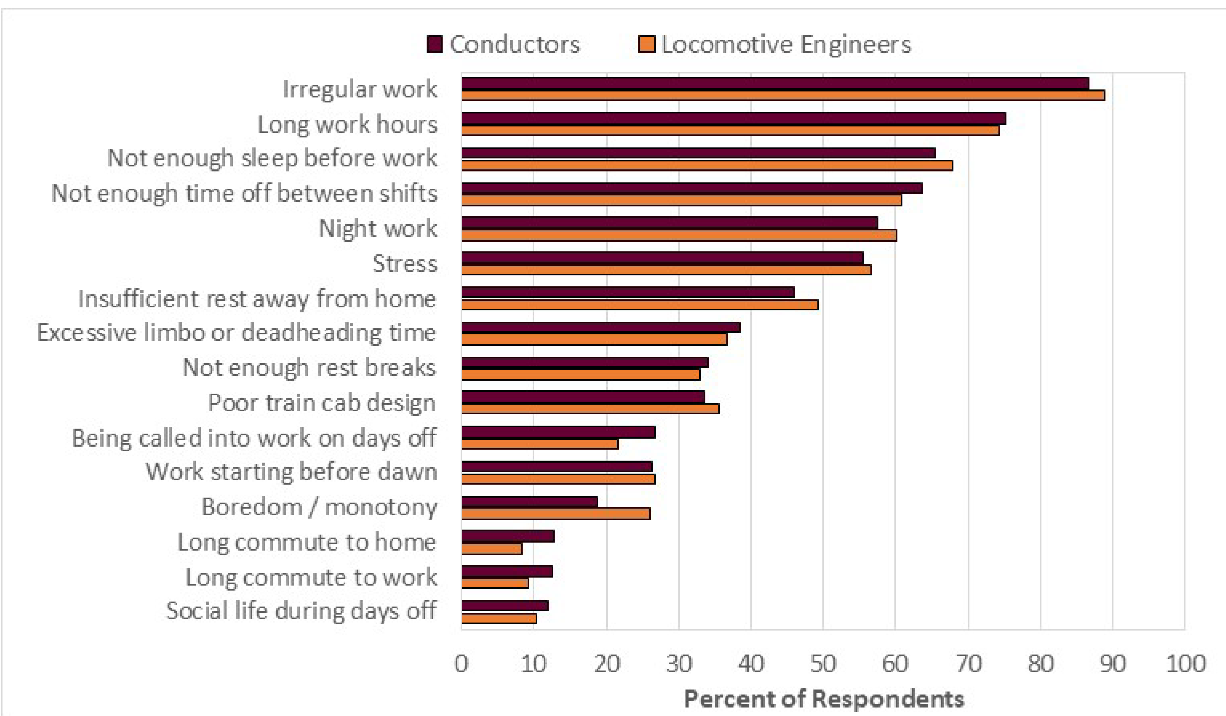

Figure 17. Frequency of factors contributing to fatigue at work

Locomotive engineers and conductors were asked when they were most likely to experience fatigue while operating a locomotive (Figure 18). Responses were quite similar across conductors and locomotive engineers, with the most frequent responses mapping well with the contributors to fatigue, such as lack of sleep, long working hours, and late nights/early morning start times.

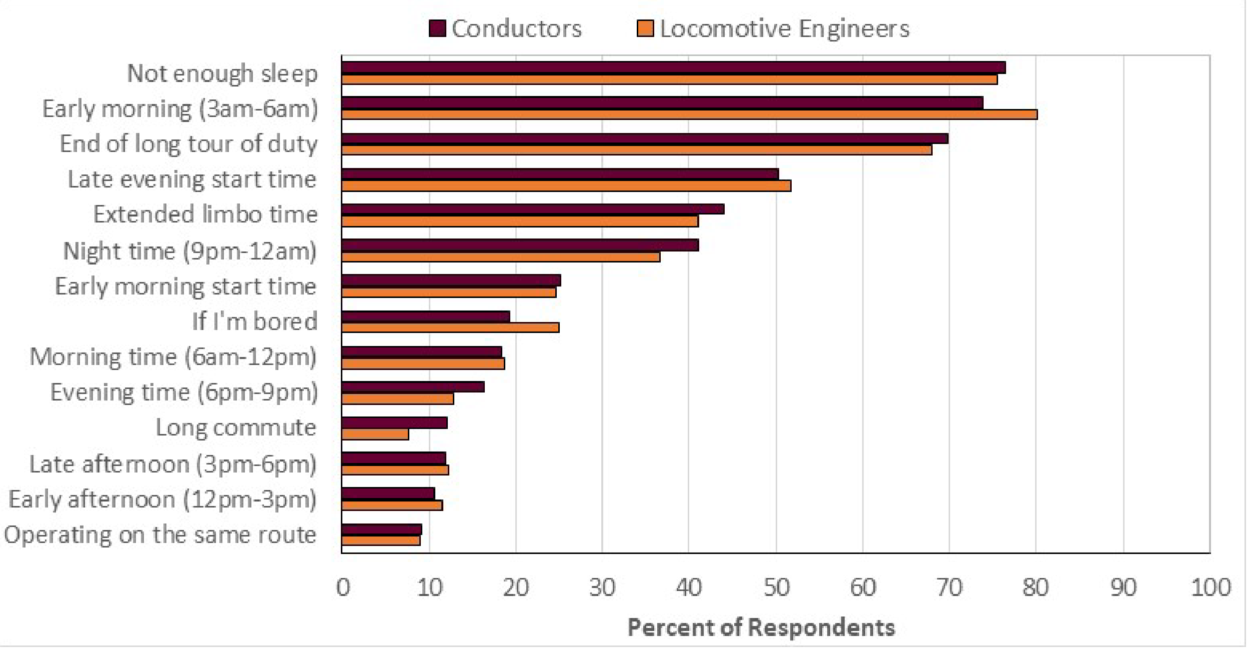

Figure 18. Instances when respondents were most likely to experience fatigue while operating a locomotive

3.4.5 Fatigue-Related Safety Events During Locomotive Operation

Just over 40 percent of locomotive engineers and 25 percent of conductors indicated they had been involved in a fatigue-related safety event while operating a locomotive in the preceding 6 months. Of those who experienced a fatigue-related safety event, approximately 50 percent of the conductors and nearly 90 percent of locomotive engineers indicated they had nodded off while controlling the locomotive (Figure 19).

Roughly one-quarter of locomotive engineers indicated the event involved either late braking for a designated stop or going too fast, while around one in five conductors indicated they had either a near-miss or missed a signal. Most of the fatigue-related safety events involved missing information or delayed responses, both of which are commonly linked to the experience of fatigue. When asked if they reported the event, only 5 percent of locomotive engineers and 9 percent of conductors indicated they had done so. Very few respondents said their company offered an anonymous reporting system for fatigue- or safety-related events (i.e., less than 4 percent of conductors and 3 percent of locomotive engineers).

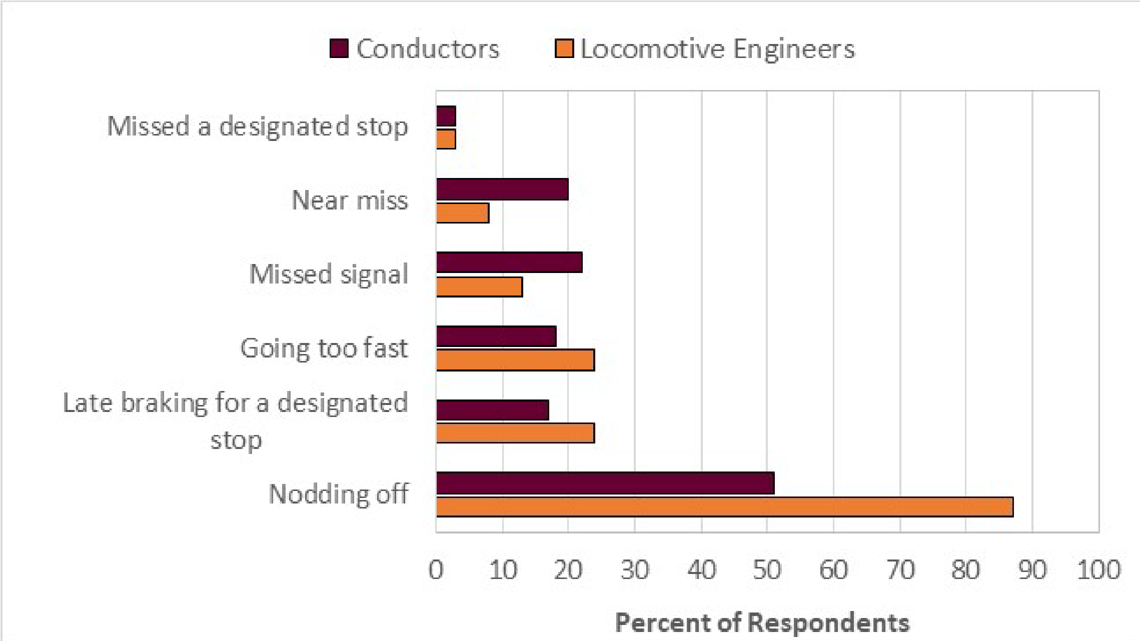

Figure 19. Type of fatigue-related safety events experienced while operating a locomotive

3.4.6 Strategies to Mitigate Fatigue

Locomotive engineers and conductors were asked to report the strategies they use to cope with fatigue when operating a locomotive and provide feedback on how effective these strategies were at reducing fatigue. A list of strategies was presented to survey respondents, and they indicated how often they used the strategy (i.e., always, often, sometimes, rarely, and never). Responses were scored by the frequency of each of these options (i.e., "always" given a higher score than "never") then ranked accordingly. The same approach was taken for ranking the effectiveness of these strategies (i.e., ranging from "very effective" to "never effective"). The effectiveness rankings mirrored the usage rankings, so the two sets of responses are combined in Table 6.

The most frequently used and most effective strategy for conductors when coping with fatigue was talking to the locomotive engineer, followed by drinking caffeine, and making additional effort to focus. For locomotive engineers, the most frequently used and effective strategy was to drink caffeine, followed by making an additional effort to focus, and talking to the conductor. Adjusting the ventilation and eating or snacking rounded out the top five strategies for coping with fatigue. Feedback from locomotive engineers and conductors highlighted that although certain strategies would be considered helpful in combatting fatigue, such as listening to music or talking on a cell phone, such activities are prohibited when operating a locomotive. Thus, these strategies received the lowest rankings despite being potentially effective (Table 6).

Table 6. Strategies to cope with fatigue, ranked by reported use and effectiveness

Ranking (Highest = 1)	Conductors	Locomotive Engineers
1	Talk to the locomotive engineer	Drink caffeine (e.g., coffee, black tea)
2	Drink caffeine (e.g., coffee, black tea)	Make additional effort to focus
3	Make additional effort to focus	Talk to the conductor
4	Adjust the ventilation (e.g., turn on air conditioning or open window)	Adjust the ventilation (e.g., turn on air conditioning or open window)
5	Eat or snack while operating locomotive	Eat or snack while operating locomotive
6	Stand while operating locomotive	Move body (e.g., walk, stretch, exercise)
7	Move body (e.g., walk, stretch, exercise)	Stand while operating locomotive
8	Drink energy drinks (e.g., Red Bull, Monster, 5-Hour Energy)	Drink energy drinks (e.g., Red Bull, Monster, 5-Hour Energy)
9	Smoke/chew tobacco	Take a quick nap
10	Take a quick nap	Smoke/chew tobacco
11	Use over-the-counter stimulant (e.g., NoDoz)	Use over-the-counter stimulant (e.g., NoDoz)
12	Listen to music	Listen to music
13	Play games/use apps on cell phone	Play games/use apps on cell phone
14	Talk on cell phone	Talk on cell phone

3.5 Highly Fatigued Locomotive Engineers and Conductors

A subset of locomotive engineers and conductors were further assessed based on responses to two specific fatigue-related questions. Those who indicated they experienced fatigue regularly (i.e., on most or every shift) and were frequently too tired to drive home after work (i.e., several times a week or after every shift) were classified as highly fatigued. Nearly 40 percent of survey respondents were classified as highly fatigued and investigated further to determine potential risk factors and safety-related outcomes for this subset of workers.

Statistical models investigated: 1) how variability in scheduling factors affected the likelihood of locomotive engineers and conductors being highly fatigued, and 2) how risk of involvement in safety-related events changes for highly fatigued locomotive engineers and conductors (i.e., compared to those who are non-highly fatigued). All models controlled for any potential impact of age and gender.

3.5.1 The Impact of Scheduling Variability on Fatigue

A logistic regression model predicted fatigue status (i.e., the likelihood of being highly fatigued) based on the usual workday schedule (i.e., the predictor of fatigue status), controlling for age and gender (Table 7). Compared to locomotive engineers who worked mostly during the day, those who worked very irregular schedules (i.e., no regular pattern to work) were 2.3 times more likely to be highly fatigued. Similarly, working mostly at night increased the odds of locomotive engineers being highly fatigued by 2.3 times compared to those who worked mostly during the day. Locomotive engineers who worked a regularly rotating schedule (i.e., regularly switched between day and night work) had 1.7 times greater odds of being highly fatigued compared to those who work mostly during the day.

Table 7. **Usual workdays for highly fatigued and non-highly fatigued locomotive engineers**

Usual Workday Comparison Level 1	Usual Workday Comparison Level 2	Odds Ratio Estimate	95% Lower Confidence Limit	95% Upper Confidence Limits
Very irregular work	Majority of work is in the day	2.32*	1.55	3.48
Very irregular work	Regular rotating work	1.36	0.99	1.87
Majority of work is at night	Very irregular work	1.01	0.85	1.19
Majority of work is at night	Majority of work is in the day	2.34*	1.53	3.57
Majority of work is at night	Regular rotating work	1.36	0.97	1.93
Regular rotating work	Majority of work is in the day	1.71*	1.04	2.84

As shown in Table 8, conductors who worked very irregular schedules were 2.8 times more likely to be highly fatigued than those who worked mostly during the day. Similarly, nightwork increased the likelihood of being highly fatigued by 2.5 times compared to day work. Irregular schedules and nightwork also increased the odds of being highly fatigued compared to regular rotating work for conductors.

Table 8. **Usual workdays for highly fatigued and non-highly fatigued conductors**

Usual Workday Comparison Level 1	Usual Workday Comparison Level 2	Odds Ratio Estimate	95% Lower Confidence Limit	95% Upper Confidence Limit
Very irregular work	Majority of work is in the day	2.82*	1.98	4.02
Very irregular work	Regular rotating work	1.86*	1.38	2.51
Very irregular work	Majority of work is at night	1.15	0.97	1.35
Majority of work is at night	Majority of work is in the day	2.46*	1.69	3.59
Majority of work is at night	Regular rotating work	1.63*	1.17	2.25
Regular rotating work	Majority of work is in the day	1.52	0.97	2.38

Variation in start time, another element of scheduling variability, was also assessed. A logistic regression model revealed that start time variation of 8 hours or more doubled the likelihood of locomotive engineers and conductors being highly fatigued compared to start time variation of less than 2 hours. Essentially, the greater the variability in start times from day-to-day, the higher the likelihood of locomotive engineers and conductors being highly fatigued. Start time variations of less than 2 hours were associated with the lowest risk of being highly fatigued compared to other start times for locomotive engineers (Table 9) and conductors (Table 10).

Table 9. **Start time variations for highly fatigued and non-highly fatigued locomotive engineers**

Varied Start Time Comparison Level 1	Varied Start Time Comparison Level 2	Odds Ratio Estimate	95% Lower Confidence Limit	95% Upper Confidence Limit
8 hours or more	Less than 2 hours	2.07*	1.60	2.67
8 hours or more	2 hours up to 4 hours	1.30	0.96	1.74
8 hours or more	4 hours up to 8 hours	1.15	0.98	1.35
4 hours up to 8 hours	Less than 2 hours	1.80*	1.35	2.38
4 hours up to 8 hours	2 hours up to 4 hours	1.12	0.82	1.55
2 hours up to 4 hours	Less than 2 hours	1.60*	1.10	2.33

Table 10. Start time variations for highly fatigued and non-highly fatigued conductors

Varied Start Time Comparison Level 1	Varied Start Time Comparison Level 2	Odds Ratio Estimate	95% Lower Confidence Limit	95% Upper Confidence Limit
8 hours or more	Less than 2 hours	1.90*	1.56	2.33
8 hours or more	2 hours up to 4 hours	1.13	0.89	1.44
8 hours or more	4 hours up to 8 hours	1.26*	1.08	1.47
4 hours up to 8 hours	Less than 2 hours	1.51*	1.20	1.90
4 hours up to 8 hours	2 hours up to 4 hours	1.12	0.86	1.45
2 hours up to 4 hours	Less than 2 hours	1.68*	1.25	2.26

Frequent switching between day and night work was also related to the likelihood of being highly fatigue. Locomotive engineers who reported more than two day/night schedule changes per week were over twice as likely to be highly fatigued compared to those with no schedule changes, one schedule change, and two schedule changes (Table 11).

Table 11. Weekly day to night schedule changes for highly fatigued and non-highly fatigued locomotive engineers

Weekly Day to Night Change Level 1	Weekly Day to Night Change Level 1	Odds Ratio Estimate	95% Lower Confidence Limit	95% Upper Confidence Limit
More than two times	Zero times	2.22*	1.66	2.97
More than two times	Once	2.19*	1.32	3.63
More than two times	Twice	2.07*	1.66	2.97
Twice	Zero times	1.07	0.73	1.57
Twice	Once	1.06	0.60	1.85
Once	Zero times	1.01	0.57	1.80

This pattern held true for conductors who switched between day and night work more than two times (Table 12). Essentially, greater variability in scheduling practices increased the likelihood of locomotive engineers and conductors being highly fatigued. All other comparisons were not significantly different for highly fatigued locomotive engineers or conductors.

Table 12. Weekly day to night schedule changes for highly fatigued and non-highly fatigued conductors

Weekly Day to Night Change Level 1	Weekly Day to Night Change Level 2	Odds Ratio Estimate	95% Lower Confidence Limit	95% Upper Confidence Limit
More than two times	Zero times	2.57*	2.00	3.29
More than two times	Once	2.48*	1.55	3.98
More than two times	Twice	1.98*	1.55	2.54
Twice	Zero times	1.30	0.92	1.82
Twice	Once	1.25	0.74	2.12
Once	Zero times	1.03	0.61	1.75

3.5.2 Safety-Related Outcomes for Highly Fatigued Locomotive Engineers and Conductors

To assess the impact of fatigue on safety, logistic regression models predicted safety-related outcomes (e.g., fatigue-related safety event while operating a locomotive) based on fatigue status (i.e., highly fatigued vs. not highly fatigued). Odds ratios indicate the likelihood of the occurrence of a safety-related event when an operator was highly fatigued with the occurrence of the same type of event when an operator was not highly fatigued (i.e., fatigue status was the predictor). Overall, highly fatigued locomotive engineers and conductors were twice as likely to experience any type of fatigue-related safety event while operating a locomotive compared to those who were not highly fatigued.

Figure 20 presents the odds ratios for specific types of fatigue-related safety events for highly fatigued locomotive engineers and conductors (i.e., compared to those who were not highly fatigued). For example, highly fatigued conductors were four times more likely to have missed a designated stop compared to conductors not highly fatigued. Similarly, highly fatigued locomotive engineers were 3.4 times more likely to have had a near miss while operating a locomotive than locomotive engineers not highly fatigued. Just under 40 percent of locomotive engineers and conductors fit the classification of being highly fatigued.

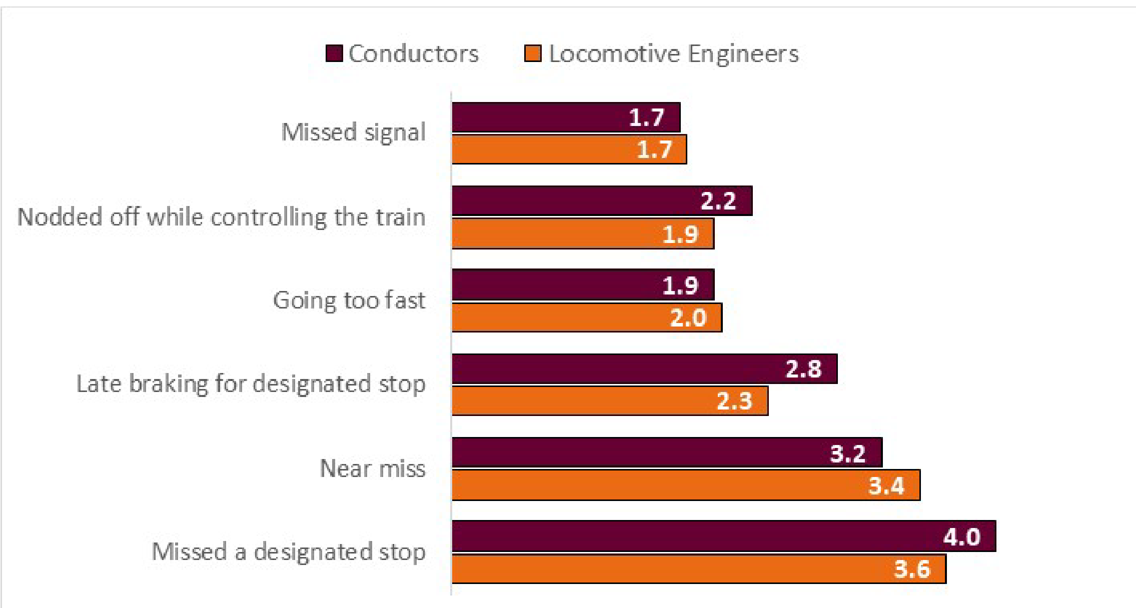

Figure 20. Odds ratios of fatigue-related safety events for highly fatigued operators compared to non-highly fatigued operators

When assessing the impact of fatigue on safety-related driving events, locomotive engineers and conductors who are highly fatigued have a greater likelihood of being involved in an adverse safety incident during their commute when compared to those that are not highly fatigued (Figure 21). Falling asleep in various driving scenarios, running off the road, nearly crashing, drifting out of the travel lane, and crashing are all safety-related outcomes that endanger the lives of other road users.

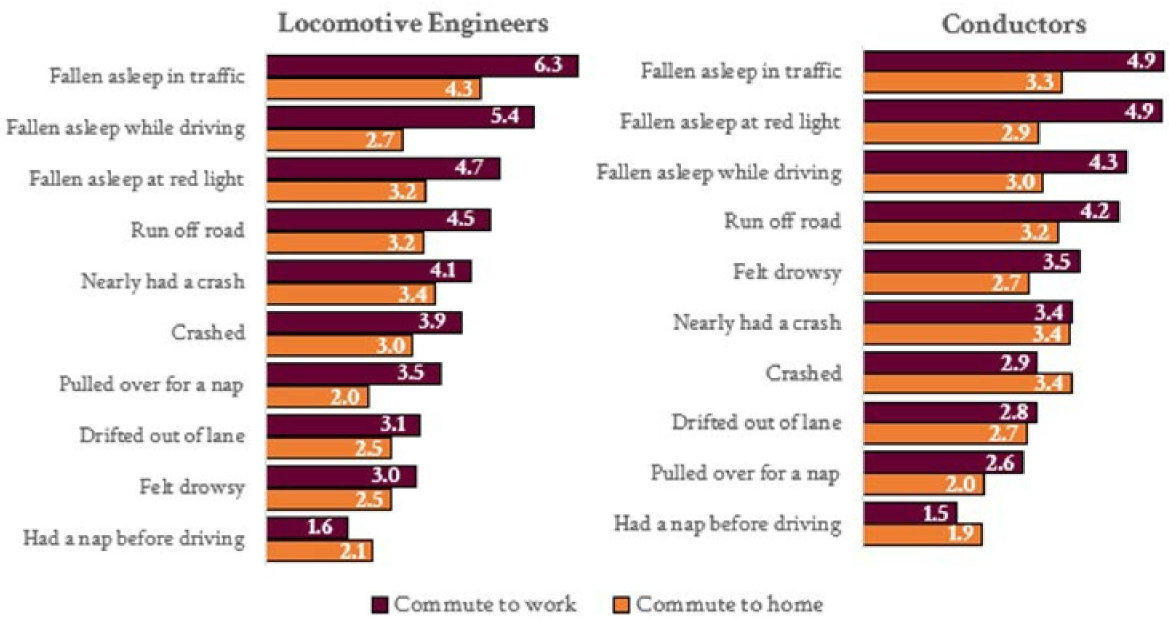

Figure 21. Odds of highly fatigued operators experiencing fatigue-related driving events during their commute compared to those who are not highly fatigued

4. Discussion

The survey results provided a high-level overview of the opinions and perceptions of locomotive engineers and conductors on a broad range of topics related to fatigue, including commute time, and the potential impact on safety. The survey results indicate that certain job conditions related to the work-rest cycle may contribute to fatigue as a major safety issue for locomotive engineers and conductors. Fatigue is a longstanding issue and concern in the railroad industry. The results of this survey indicate the importance of considering commute time in fatigue mitigation and help to highlight other contributors to fatigue as well as the potential safety impacts fatigue may have on the performance of locomotive engineers and conductors both on the job and during their commutes to and from work.

Variability in scheduling appears to be a significant factor that contributes to the experience of fatigue for locomotive engineers and conductors. More than four out of five locomotive engineers and conductors reported day-to-day start time variability of at least 4 hours, and more than 90 percent reported two or more changes from day to night work in a 1-week period. This variability and frequent switching between day and night work is not conducive to recovery between shifts and has been shown to impact sleep quality due to circadian rhythm interruption. Interestingly, despite over 90 percent of locomotive engineers and conductors reporting that they were provided with a train lineup, which theoretically should reduce some uncertainty and unpredictability associated with their schedules, around three-quarters of locomotive engineers and conductors indicated that the information provided in the lineup was very unreliable. Having to operate with unreliable information may contribute to fatigue and levels of stress.

One of the most impactful analyses completed on these data was on the subset of locomotive engineers and conductors who were classified as highly fatigued. Highly fatigued locomotive engineers and conductors were those who indicated they frequently experienced fatigue both at work (i.e., while operating a locomotive) and during their commutes to and from work (i.e., while driving). OR analysis of the survey conducted for this project revealed that highly fatigued locomotive engineers and conductors had up to 6 times greater odds of being involved in a fatigue-related driving event during their commute than non-highly fatigued locomotive engineers and conductors. Highly fatigued locomotive engineers had nearly 4 times greater odds of crashing during their commute than non-highly fatigued locomotive engineers. Falling asleep during a commute while driving, stopped at a red light, or in traffic had the top three highest odds for both locomotive engineers and conductors who were highly fatigued compared to those who were not. While fatigue in the workplace is a widely acknowledged issue, fatigue during commuting to and from work is largely overlooked, despite the very real prevalence and danger not just to the driver, but also to the public and other road users. Long commutes (i.e., 1 hour or more) can add significantly to the workday and turn a 12-hour day into a 14- or 15-hour day, with commute times also encroaching on inter-shift rest and recovery opportunities. Indeed, the commute time duration analyses revealed that locomotive engineers and conductors who reported extra-long commute times (i.e., greater than 1 hour) had greater odds of being involved in a fatigue-related driving event than those who had a medium or short commute. Conductors with an extra-long commute were 9 times more likely to be involved in a crash than those with a short commute.

Limitations

Survey data is self-reported based on questions in the survey; thus, it is not objective and cannot be quantified in the same way as a laboratory study. It also cannot be used to establish cause and effect relationships. However, surveys are an excellent way to gather information from a representative sample of a population that is typically generalizable and reliable about a population as a whole, in this case conductors and locomotive engineers. This survey data provides a representative picture of commute times and other significant work-rest characteristics for locomotive engineers and conductors.

When completing data validation, the most conservative approach was taken, with exclusion criteria set up to eliminate repeat entries from the same IP address, for example. Given the number of valid responses in the final dataset (i.e., just over 9,000) and the overwhelming pattern of responses throughout the survey, there would have to be many fake or repeat surveys that made it through the exclusion criteria to have a significant impact on the results.

Finally, this survey was intended for locomotive engineers and conductors; however, that is not to say that fatigue is not an issue for other rail workers, such as dispatchers or signalmen. It would be difficult to create a survey comprising questions that adequately address the most relevant issues for all rail workers due to variance in their work routines and responsibilities. Questions need to be tailored to the specific tasks and characteristics of the job, as was done in this case, to provide information of value.

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Appendix A. Survey and Announcements

VIRGINIA TECH TRANSPORTATION INSTITUTE

Default Question Block

Project Title: Fatigue and Safety of Locomotive Engineers and Conductors
Investigator: Naomi Dunn, Ph.D., from the Virginia Tech Transportation Institute (VTTI)

The purpose of this research study is to better understand the factors that contribute to fatigue in locomotive engineers and conductors, including commute times to and from work. This research will assess opinions and perspectives of locomotive engineers and conductors with an online survey. To participate, you must be a current locomotive engineer or conductor on either a freight or passenger service. The survey is anonymous and will not collect any personally identifying information. Please express your honest opinions.

The survey will take approximately 15-20 minutes to complete though you can take as much time as you need to complete it. The risks associated with this survey include possible discomfort at sharing your experience and opinions. You may choose not to answer a question if you prefer not to or you can withdraw your responses at any time by simply closing the web browser before submitting your responses.

All information collected in this survey will be kept confidential and will be stored on secure access-restricted servers at

VTTI. Completion is voluntary and your participation, or non-participation, will not impact your employment in any way. Study findings will be presented as aggregated and anonymous results (e.g., 78% of survey respondents were male). A final report will be generated from this work.

We appreciate your time and attention spent answering the survey. You will not be compensated financially for this research; however, your contribution to this research is valuable. Assessing the important factors that contribute to fatigue and the impact these factors have on locomotive engineer and/or conductor safety is necessary to find solutions that benefit rail workers, management, and the rail industry. This information is a critical first step in developing effective fatigue-mitigation strategies for locomotive engineers and conductors.

If you have any questions prior to starting this survey, you may contact Naomi Dunn at ndunn@vtti.vt.edu.

This research project has been approved, as required, by the Institutional Review Board for Research Involving Human Subjects at Virginia Polytechnic Institute and State University. If you should have any questions about the protection of human research participants regarding this study, you may contact the Virginia Tech Institutional Review Board for the Protection of Human Subjects [irb@vt.edu or (540) 231-3732].

By clicking "NEXT" to continue to the survey, you confirm that you are a current locomotive engineer or conductor (freight and/or passenger). In addition, you acknowledge that you have read and understand the consent information above.

Are you currently a locomotive engineer or conductor for a freight or passenger service?

- ○ Yes
- ○ No
- ○ I don't know

Thank you for your interest in this research. Unfortunately, you are not eligible to complete this survey as it is open to current locomotive engineers and conductors only. If you feel you have received this message in error, please contact the Principal Investigator for the study: Naomi Dunn (ndunn@vtti.vt.edu)

OMB CONTROL NUMBER: 2130-0628 EXPIRATION DATE: 09/30/2022

Paperwork Reduction Act Burden Statement A federal agency may not conduct or sponsor, and a person is not required to respond to, nor shall a person be subject to a penalty for failure to comply with a collection of information subject to the requirements of the Paperwork Reduction Act

unless that collection of information displays a currently valid OMB Control Number. The OMB Control Number for this information collection is 2130-0628. Public reporting for this collection of information is estimated to be approximately 20 minutes per scenario, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, completing and reviewing the collection of information. All responses to this collection of information are voluntary. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to: Information Collection Clearance Officer, Federal Railroad Administration, 1200 New Jersey Avenue, SE, Washington DC 20590.

1. How old are you?

- ○ Less than 25 years

◯ 25 to 34 years
◯ 35 to 44 years
◯ 45 to 54 years
◯ 55 to 64 years
◯ 65 + years

2. What is your gender?

◯ Male
◯ Female

3. Are you a:

◯ Locomotive engineer
◯ Conductor

4. Do you work on a:

◯ Freight train
◯ Passenger train

5. In total, how long have you worked as a locomotive engineer or conductor? (ex: 5 years and 3 months)

Number of Years

Number of Months

6. In total, how long have you worked in the rail industry? (ex: 5 years and 3 months)

Number of Years

Number of Months

*ANSWER THE NEXT SET OF QUESTIONS THINKING ABOUT THE **LAST MONTH OF WORK:***

7. In the LAST MONTH, how many *hours per day* did you usually work? (i.e., sign on to sign off)?

Number of Hours per Day

8. In the LAST MONTH, how many *days per week* did you usually work?

Number of Days per Week

9. In the LAST MONTH, which category best describes your usual work?

○ Majority of work is at night
○ Majority of work is in the day

○ Regular rotating work (tours of duty switch between day and night on a regular roster)

○ Very irregular work (i.e., tours of duty have no regular pattern)

10. In the LAST MONTH, how many times were you called in for work on your days off?

Number of times called in for work ☐

11. In the LAST MONTH, how much did the start time of your tours of duty vary from day to day?

○ Less than 2 hours

○ 2 hours or more, but less than 4 hours

○ 4 hours or more, but less than 8 hours

○ 8 hours or more

12. In the LAST MONTH, how often did your tours of duty change from day work to night work during a one-week period?

○ Zero times

○ Once

○ Twice

○ More than two times

13. On average, in the LAST MONTH, how many hours did you sleep per day (*i.e., in a 24-hour period*) during a one-week period?

Number of hours slept per day ☐

14. Was this sleep typically during the daytime or nighttime?

- ○ Day
- ○ Night

15. The following statements are about your experience of FATIGUE and STRAIN at work OVER THE LAST FEW MONTHS.
Choose from "Strongly Disagree" to "Strongly Agree" which best indicates your response.

	Strongly Disagree	Disagree	Slightly disagree	Neither agree nor disagree	Slightly agree	Agree
I never have enough time between work shifts to recover my energy completely	○	○	○	○	○	○
I usually feel exhausted when I get home from work	○	○	○	○	○	○
Even if I'm tired from one shift, I'm usually refreshed by the start of the next shift	○	○	○	○	○	○
I rarely recover my energy fully between work shifts	○	○	○	○	○	○
Recovering from work fatigue between work shifts isn't a problem for me	○	○	○	○	○	○
I'm often still feeling fatigued from one shift by the time I start the next one	○	○	○	○	○	○

16. In the LAST MONTH, how did you normally commute from home to work/from work to home? ***(Check main mode of transport)***

- ○ Drive my own car

- ○ Drive my own motorcycle
- ○ Public transportation (train, bus, etc.)
- ○ Car/van pool
- ○ Ride a bicycle
- ○ Walk
- ○ Other

17. In the LAST MONTH, if you drove your own car, did you normally commute to/from work alone?

- ○ Usually alone
- ○ Usually not alone
- ○ N/A – I didn't drive my own car

18. In the LAST MONTH, on how many days during a work week did you commute from home to work?

- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5
- ○ 6
- ○ 7

19. In the LAST MONTH, on days when you commuted to work, how long did it usually take you to get:

To work from home? (in minutes) [ ]

To home from work? (in minutes) [ ]

20. Did you typically make stops or detours during your commute TO WORK from home? (e.g., stop at shops, pick up/drop off children)

- ◯ Yes
- ◯ No

21. Did you typically make stops or detours during your commute TO HOME from work? (e.g., stop at shops, pick up/drop off children)

- ◯ Yes
- ◯ No

22. In the LAST MONTH, approximately how many miles was your commute, one way?

Number of miles one-way [ ]

*ANSWER THE NEXT SET OF QUESTIONS THINKING ABOUT THE **LAST SIX MONTHS OF WORK:***

23. In the LAST 6 MONTHS, how frequently have you felt too tired to drive home after work?

- ◯ After every tour of duty
- ◯ Several times a week
- ◯ About once a week
- ◯ Once every few weeks

- ◯ Once every couple of months
- ◯ Rarely (i.e., once in 6 months)
- ◯ Never

24. In the LAST 6 MONTHS, during your commute TO WORK from home, have you: ***(Check all that apply)***

- ☐ Crashed
- ☐ Felt drowsy
- ☐ Nearly had a crash
- ☐ Fallen asleep while stopped in traffic
- ☐ Drifted out of the lane of traffic
- ☐ Fallen asleep while driving
- ☐ Pulled over to take a nap
- ☐ Fallen asleep while stopped at a red light
- ☐ Had to have a nap at home before driving to work
- ☐ Run off the road in your vehicle

25. In the LAST 6 MONTHS, during your commute TO HOME from work, have you: ***(Check all that apply)***

- ☐ Crashed
- ☐ Felt drowsy
- ☐ Nearly had a crash
- ☐ Fallen asleep while stopped in traffic
- ☐ Drifted out of lane of traffic
- ☐ Fallen asleep while driving
- ☐ Pulled over to take a nap
- ☐ Fallen asleep while stopped at a stop light
- ☐ Had to have a nap at home before driving to work
- ☐ Run off the road in your vehicle

26. In the LAST 6 MONTHS, how often have you experienced fatigue while operating a train?

- ◯ Every tour of duty
- ◯ On most tours of duty
- ◯ About half the tours of duty
- ◯ Occasionally
- ◯ Rarely
- ◯ Never

27. To what degree do you think fatigue impacts your operation of a train?

- ◯ No impact
- ◯ A minimal impact
- ◯ Moderate impact
- ◯ A significant impact

28. In the LAST 6 MONTHS, when were you most likely to experience fatigue while operating a train? ***(Check all that apply)***

- ☐ Early morning (3am to 6am)
- ☐ Morning (6am to 12pm)
- ☐ Early afternoon (12pm to 3pm)
- ☐ Late afternoon (3pm to 6pm)
- ☐ Evening (6pm to 9pm)
- ☐ Night (9pm to 12am)
- ☐ After extended limbo or deadheading time
- ☐ Other ____________
- ☐ If I haven't had enough sleep
- ☐ If I started work really early in the morning
- ☐ Towards the end of a long tour of duty
- ☐ If I operate on the same route a few times in a row
- ☐ If I started work late in the evening
- ☐ After a long commute to work
- ☐ If I'm feeling bored

29. In the LAST 6 MONTHS, how long after the start of your tour of duty were you most likely to feel fatigued?

Number of Hours ☐

30. In the LAST 6 MONTHS, what factors contributed most to your fatigue at work? *(Check all that apply)*

- ☐ Night work
- ☐ Irregular work
- ☐ Long work hours
- ☐ Not enough sleep before work
- ☐ Long commute to work
- ☐ Work starting early morning (i.e., before dawn)
- ☐ Long commute to home
- ☐ Boredom / monotony
- ☐ Stress
- ☐ Insufficient rest away from home
- ☐ Not enough time off between work
- ☐ Poor train cab design
- ☐ Social life during days off
- ☐ Not enough rest breaks
- ☐ Excessive limbo or deadheading time
- ☐ Being called into work on days off

31. In the LAST 6 MONTHS, have you experienced a fatigue-related safety incident when operating a train?

- ○ Yes
- ○ No

32. If yes, what happened? *(Check all that apply)*

- ☐ Missed signal
- ☐ Crash

☐ Near miss
☐ Nodded off while controlling the train
☐ Missed designated stop
☐ Late braking for designated stop
☐ Going too fast
☐ Other

33. **Did you report the incident?**

○ Yes
○ No

34. **Does your company offer an anonymous reporting system for fatigue-related or safety-related incidents?**

○ Yes
○ No
○ Not Sure

35. **In the LAST 6 MONTHS, how often have you used each of the following strategies to cope with fatigue when operating a train?** ***(Rate each strategy separately)***

	Never	Rarely	Sometimes	Often	Always
Listen to music	○	○	○	○	○
Eat or snack while operating train	○	○	○	○	○
Drink caffeine (e.g., coffee, black tea)	○	○	○	○	○
Make additional effort to focus	○	○	○	○	○

	Never	Rarely	Sometimes	Often	Always
Adjust the ventilation (e.g., turn on air con or open window)	◯	◯	◯	◯	◯
Use over the counter stimulant (e.g., NoDoze)	◯	◯	◯	◯	◯
Take a quick nap	◯	◯	◯	◯	◯
Drink energy drinks (e.g., Red Bull, Monster, 5-Hour Energy)	◯	◯	◯	◯	◯
Talk to conductor or engineer	◯	◯	◯	◯	◯
Stand while operating train	◯	◯	◯	◯	◯
Talk on cell phone	◯	◯	◯	◯	◯
Move body (i.e., walk, stretch, exercise)	◯	◯	◯	◯	◯
Play games/use apps on cell phone	◯	◯	◯	◯	◯
Smoke/chew tobacco	◯	◯	◯	◯	◯

36. In your opinion, how effective are the following strategies to reduce fatigue while operating a train (i.e., regardless of whether you use the strategy)? ***(Rate each strategy separately)***

	Never effective	Slightly effective	Somewhat effective	Effective	Very effective
Listen to music	◯	◯	◯	◯	◯
Eat or snack while operating train	◯	◯	◯	◯	◯
Drink caffeine (e.g., coffee, black tea)	◯	◯	◯	◯	◯
Make additional effort to focus	◯	◯	◯	◯	◯

	Never effective	Slightly effective	Somewhat effective	Effective	Very effective
Adjust the ventilation (e.g., turn on air con or open window)	○	○	○	○	○
Use over the counter stimulant (e.g., NoDoze)	○	○	○	○	○
Take a quick nap	○	○	○	○	○
Drink energy drinks (e.g., Red Bull, Monster, 5-Hour Energy)	○	○	○	○	○
Talk to conductor or engineer	○	○	○	○	○
Stand while operating train	○	○	○	○	○
Talk on cell phone	○	○	○	○	○
Move body (i.e., walk, stretch, exercise)	○	○	○	○	○
Play games/use apps on cell phone	○	○	○	○	○
Smoke/chew tobacco	○	○	○	○	○

37. Does your company provide you with a computer train line-up?

○ Yes

○ No

○ Not sure

38. How reliable is the information provided in the computer train line-up?

○ Very reliable

○ Somewhat reliable

○ Not particularly reliable or unreliable
○ Somewhat unreliable
○ Very unreliable

39. In the LAST MONTH, what percentage of computer train line-ups you received were accurate?

% of accurate line-ups received

40. Does your current company have a fatigue management policy?

○ Yes
○ No
○ Not sure

41. Does your current company educate employees about fatigue?

○ Yes
○ No
○ Not sure

42. How much of a problem is fatigue for YOU PERSONALLY in your job?

○ A major problem
○ A substantial problem
○ A minor problem
○ Not a problem at all

43. **How much of a problem is fatigue for locomotive engineers and conductors IN GENERAL?**

- ○ A major problem
- ○ A substantial problem
- ○ A minor problem
- ○ Not a problem at all

44. **How well do you believe fatigue is managed in the rail industry?**

- ○ Extremely badly
- ○ Quite badly
- ○ Ok
- ○ Quite well
- ○ Extremely well

BLET asks members to participate in fatigue research study

FEBRUARY 9, 2022 | FRA, News

WASHINGTON, D.C., February 9 — The Brotherhood of Locomotive Engineers and Trainmen (BLET), working in collaboration with the Federal Railroad Administration (FRA) and the Virginia Tech Transportation Institute, is asking locomotive engineers and conductors to participate in a confidential survey regarding fatigue.

The goal of the research study is to better understand the factors that contribute to fatigue in locomotive engineers and conductors. To participate, you must be a current locomotive engineer or conductor on either a freight or passenger service.

Officials with Virginia Tech stress that the survey is anonymous and will not collect any personally identifying information. According to the survey's creators: "Your contribution to this research is valuable. Assessing the important factors that contribute to fatigue and the impact these factors have on locomotive engineer and/or conductor safety is necessary to find solutions that benefit rail workers, management and the industry. This information is a critical first step in developing fatigue-mitigation strategies for locomotive engineers and conductors."

"We believe it is helpful for outside organizations, including academic institutions like Virginia Tech, to get information directly from our members. This survey provides a way for that to happen. BLET will always try to ensure our members have the opportunity to provide vital fatigue data for researchers," BLET National President Dennis R. Pierce said.

The survey should take 10-15 minutes to complete, but respondents can take as much time as they wish. It is available at:

https://survey.az1.qualtrics.com/jfe/form/SV_6PPxWtBGxVzZaCh

Rail members' input sought by FRA for fatigue survey

February 9, 2022

Home > News > Transportation > Amtrak/Commuter > Amtrak/Commuter News > Rail members' input sought by FRA for fatigue survey

The Federal Railroad Administration is asking T&E rail members of the SMART Transportation Division to participate in a wide-reaching survey of T&E personnel on the topic of fatigue.

Participants working in T&E roles in either passenger or freight service are highly encouraged to help FRA's Office of Research, Development & Technology: Human Factors Division gather data via the 49-question survey.

"It's an opportunity to provide any feedback about fatigue, work schedules and work/life balance," FRA officials said.

Topics include typical work schedules over a period of days, weeks and months, members' sleep cycles and their commute times, i.e. "the time (or distance) from home to work and vice versa, with 'work' referring to the location where crews start/finish their shift. 'Home' may also include away sites where crew members rest/sleep away from their personal home."

Follow this link to participate in this important survey.

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Abbreviations and Acronyms

ACRONYM	DEFINITION
BLET	Brotherhood of Locomotive Engineers and Trainmen
CI	Confidence interval
CMV	Commercial motor vehicle
DOT	Department of Transportation
FAA	Federal Aviation Administration
FAST	Fatigue Avoidance Scheduling Tool
FRA	Federal Railroad Administration
FRMS	Fatigue Risk Management System
HOS	Hours of service
IR	Inter-shift recovery
MOW	Maintenance of Way
NIOSH	National Institute for Occupational Safety and Health
NTSB	National Transportation Safety Board
OFER	Occupational Fatigue Exhaustion Recovery
OR	Odds ratio
RSSB	Rail Safety and Standards Board
SMART	International Association of Sheet Metal, Air, Rail, and Transportation Workers
VTTI	Virginia Tech Transportation Institute