Fatigue Science Faller Report – Introduction and Explanation:

The BC Forest Safety Council and Fatigue Science partnered to run a pilot project to test the effectiveness and feasibility of measuring sleep patterns and fatigue levels of fallers in Coastal BC. Fatigue Science has the technology to measure workers' sleep quantity and quality with a wrist watch device called the readiband. The data from the readiband is then analyzed using proven software to calculate fatigue levels.

The following report provides a summary of the information that was gathered. Individual results are kept strictly confidential by Fatigue Science, however, each participant in the program was sent their results and if a sleep disorder was suspected, they were advised to follow up with a physician.

In order to fully understand the results of the report, it is important to understand some of the assumptions that were made during the analysis.

1) Shift Start and End Times

An assumption was made for the analysis of this data that the average start time for the fallers was 7 am and the shift was finished at 3 pm. This may be a fairly accurate description of an average day working as a faller but it is important to understand that quite often working days can be outside of this 7 am to 3 pm window, especially if there are long drives to get to the work site or if there are unusual circumstances that require a longer working day, such as weather or production deadlines.

2) Days Worked During Shift

There were 2 groups that were measured during the study, camp based fallers and fallers that drove (commuted) to their work site each day. One of the assumptions was that the work shift was Monday to Friday. This may have been accurate for the commuting fallers but fallers staying in camp typically work longer shifts, such as a 10 day on/ 4 days off schedule.

An important conclusion from this study is that relying on the readiband data alone does not give the full picture of the work and sleep schedule and a daily journal with work shift information is required for a full analysis.

3) Other Sleep Opportunities

Discussions with fallers who participated in the pilot project identified that the sleep provided through naps may not have been accurately captured. The practice of napping after the work shift while at camp is quite common and would provide additional sleep that would increase the sleep levels from the average of 6.5 hours per day.

4) Impairment Level

The level at which impairment occurs is set at 70% effectiveness which is a percentage that is calculated by the fatigue modelling software used by Fatigue Science. This 70% number is equivalent to the level of impairment seen with someone who has a blood alcohol content of 0.08.

In the study it was found that the fallers very rarely fell below this 70% number which is a good result because it shows that they are not often impaired by fatigue at work. However, workers who are above this 70% should not be considered to be working at their optimum levels. In high risk professions, the goal should be working at 90% or greater to be falling at their most productive and safest level. Fatigue Science works with elite, professional athletes and the level they recommend that athletes are at is 90% or greater at game times for best performance. The demands on industrial athletes such as fallers are similar to professional athletes and risks are higher so the goal should be to be at this same level of 90% or higher.

For further information on this report, please contact Gerard Messier with the BC Forest Safety Council at 1-877-741-1060 or messier@bcforestsafe.org.

FATIGUE SCIENCE

BC Forest Safety Council

Tree Faller Fatigue Study: Readiband Summary & Analysis

Data collected: 2014-15
Analysis completed: August 2015

BC Forest Safety

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FAST Analysis & Technology Overview

Objective

The purpose of this report is to present a high-level sleep, fatigue and accident risk assessment of BC tree fallers for the BC Forest Safety Council. Readibands were deployed with 80 fallers (across 9 sites) over the course of fifteen months. Of all the Readibands assessed, 62 were determined to have valid data for analysis.

This report will summarize:

- Readiband sleep data collected from tree fallers
- Comparison of sleep results between fallers who commute daily and those who reside in camp
- Analysis of average worker fatigue risk based on daytime work schedule and actual sleep obtained
- Dayshift human factors accident risk rating
- Percentage of fallers with reporting results which warrant further screening or review

What we did

Collected sleep data
for a target range of 3-4 weeks per group
(actual range of data varied)

Aggregated and analyzed
sleep data for tree fallers along with their
work schedule

Assessed work schedule*
5 days on, 2 days off
Work shifts: 7:00 AM to 3:00 PM

* For the purposes of this analysis, Fatigue Science established average work schedule to be Monday to Friday, from 7:00 AM to 3:00 PM

Readiband data summary

Fallers were assessed in two groups: workers sleeping in camps and daily commuters. There were four groups (companies) sleeping in camps and five groups commuting to work sites on a daily basis. For the purpose of maintaining anonymity, the subgroups will be referred to by letters as follows:

Camp: A,B,C,D
Commute: A,B,C,D,E

Regarding Readiband Data and Effectiveness Scoring

Readiband collects and analyzes wrist-movement data to identify the quantity of sleep, quality of sleep, and timing of sleep and wake cycles for individual users. This data is further processed using a patented bio-mathematical model to demonstrate the users change in performance effectiveness over time.

Effectiveness is scored out of 100. A score above 90 indicates a well-rested and optimally effective individual. A score between 71-90 indicates some reduction in reaction time and effectiveness but fatigue risk remains statistically low. A score of 70 and below indicates a reaction time and effectiveness that is reduced by 42% (or more) and equivalent to having a blood alcohol content of 0.08. Individuals who spend working hours at 70 or below have high-fatigue and are at a significantly increased risk of having a fatigue-related human factors incident.

Introduction to FAST & Methodology

The Fatigue Avoidance Scheduling Tool (FAST) was originally developed for the United States Army as a computerized fatigue prediction tool to help mission planners minimize the effects of human fatigue in their operations.

FAST uses a patented, bio-mathematical predictive model known as SAFTE (Sleep, Activity, Fatigue and Task Effectiveness), which was developed by Dr. Hursh of the Walter Reed Army Institute of Research. The SAFTE model is based on over twenty years of sleep and circadian research and has been validated to make accurate predictions of cognitive performance for adult subjects under a broad range of conditions. Performance is dependent on the current balance of the sleep regulation process, the circadian process, and sleep inertia - all of which are incorporated into the SAFTE model's predictions (For further explanation of these and other relevant terms, please review Appendix A at the end of this report).

Based on sleep data and time of day circadian factors, FAST is able to demonstrate a minute-by-minute measured prediction of reaction time and fatigue-related accident risk in workers. By utilizing the predictive modeling of FAST, Health & Safety Managers can identify periods of potential reduced performance during their work schedule and apply measures to reduce the workplace accident risk.

FAST is the most scientifically validated program for fatigue modeling, but it is not without its limits, which are outlined in Appendix C at the conclusion of this document

Data inputs

Data Inputs & Parameters used in FAST

Input	Notes from BCFSC	Notes from Fatigue Science
Shift name	Of the 9 sites in which Readibands were deployed, 4 were 'camp' environments and 5 were 'commute environments'	Data for all crews were aggregated by site type (camp vs. commute) before analysis.
Schedule start date		Data was collected across 15 months. For the purpose of this analysis the schedule was processed starting August, 2015. Will refer to day # for the purposes of reporting.
Schedule duration		60-days of schedule data were reviewed in this analysis.
Location	Vancouver, British Columbia	Time zone -8 (-7 DST)
Proportion of workers sleeping in camps	45.2%	-
Proportion of workers commuting to work sites	54.8%	-
Is daylight savings time observed at work site?	Yes	-
Work Intervals		5 Days, 2 Off
Shift duration	8 hours	Day shift: 07:00 - 15:00 (8 hours)
Sleep		See Overall sleep profile (pg.6)

Readiband Sleep Profile (Average timing and duration of sleep)

	Sleep prior to weekdays (work)		Sleep prior to weekends (rest)		Overall	
	Camp	Commute	Camp	Commute	Camp	Commute
Average Sleep Onset	10:29 PM	10:01 PM	10:45 PM	10:59 PM	10:34 PM	10:17 PM
Average Wake Time	5:48 AM	5:02 AM	6:18 AM	6:33 AM	5:57 AM	5:28 AM
Average Sleep Duration	6.5 hours	6.3 hours	6.7 hours	6.7 hours	6.6 hours	6.4 hours

Notes regarding camp and commute worker sleep profiles:

Based on the data retrieved, camp and commute workers are sleeping on average 6.6 and 6.4 hours a night respectively. The participants slept slightly more per night during their days off, both receiving on average 6.7 hours of sleep, than their overall averages of 6.5 (camp) and 6.3 (commute) hours prior to scheduled work days. Employees did improve their sleep debt on their days off, but are still not reaching an optimal 7-9 hours of sleep a night.

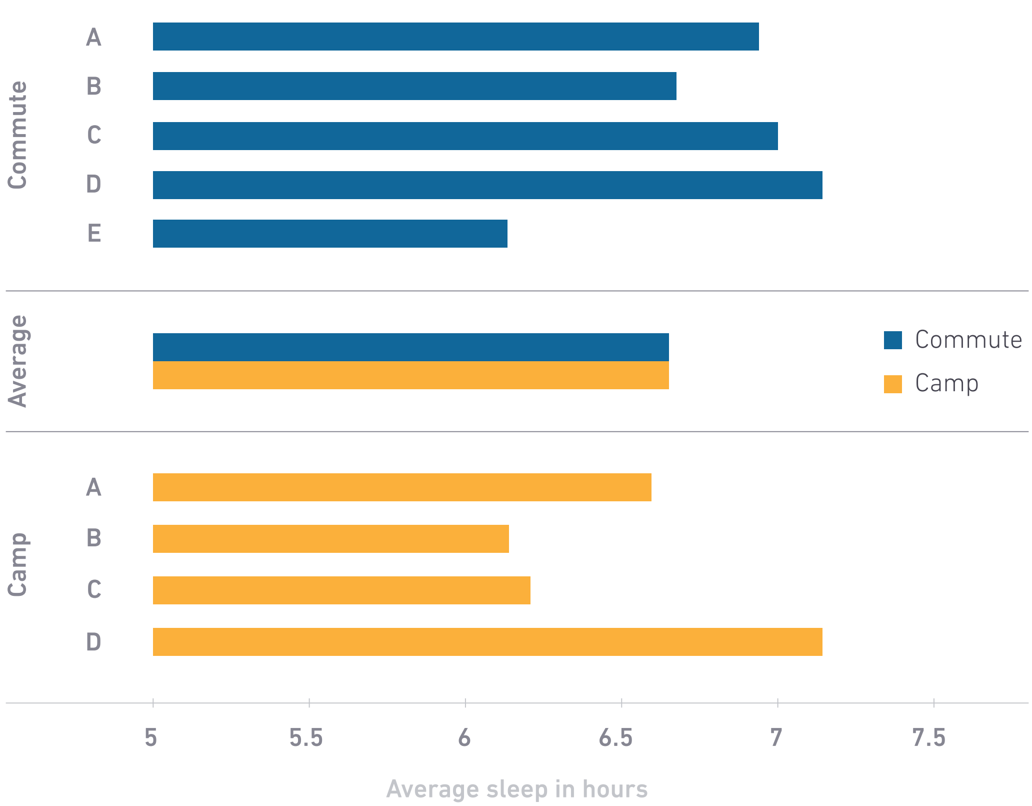
Readiband Sleep Summaries (Actual vs. Optimal)

	Metric	Camp	Commute	Optimal range
Average for all data collected	**Sleep duration** (Amount of time spent sleeping)	6.6 hours	6.4 hours	7-9 hours
	Sleep latency (Amount of time it takes to fall asleep once in bed)	50 minutes	53 minutes	10-20 minutes
	Sleep efficiency (Percentage of time in bed actually spent sleeping)	77.0%	77.3%	80-100%
	Wake episodes (Average number of times per night participants wake up)	3.7	3.6	<7

Average sleep obtained by subgroup/site

Average sleep obtained prior to weekdays-commute vs. camp

Average sleep obtained prior to weekends-commute vs. camp



Fatigue analysis

FAST graphical display

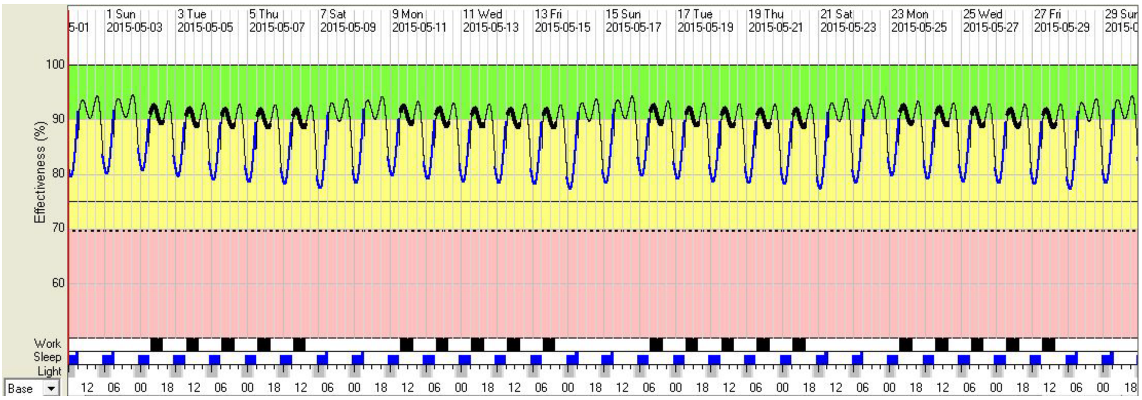


Fig. 1a - FAST graphical display for workers staying in **camp** based on a 30-day period

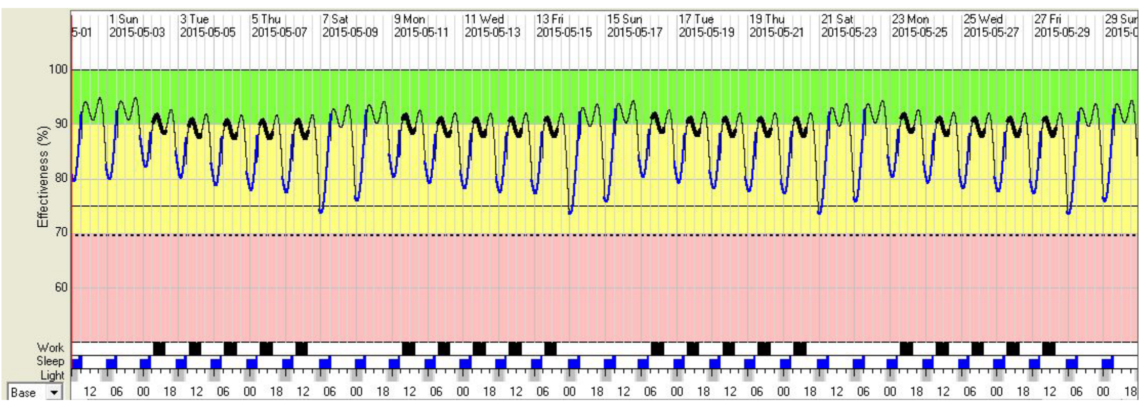


Fig. 1b - FAST graphical display for **commuters** based on a 30-day period

The FAST graphical displays 1a and 1b represent one cycle of the 30-day schedule along the X-axis from left to right. Each 24-hour period is represented by a single 'tooth-shaped' curve that resembles the one below (see Fig. 2). The FAST graph demonstrates the overall continuous change in performance over time for the BCFSC workers based on actual sleep and real schedule inputs. The FAST graphs incorporate all currently scheduled work shifts (indicated by **thick black lines**) and aggregate actual sleep profile data (indicated by **blue lines**).

Potential performance effectiveness is indicated on the vertical (Y) axis. It is important to note that we have defined the range in which a worker should be while on the job at 70 or higher, 80 or higher is optimal. At 70 a person or crew will have a reduction in cognitive effectiveness and reaction time equivalent to having a blood alcohol content (or BAC) of 0.08 and a statistically significant increased risk of having a fatigue-related accident.

For your visual reference, this 70 range is indicated on the FAST graph in the pink colored zone. For additional information about the Performance Effectiveness Scores produced by FAST, please see **Appendix B**.

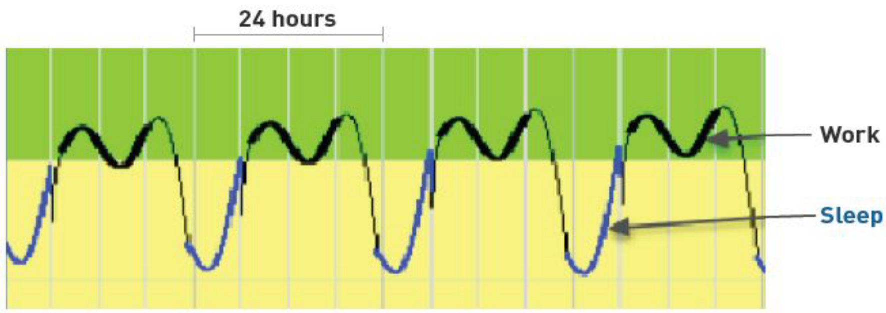
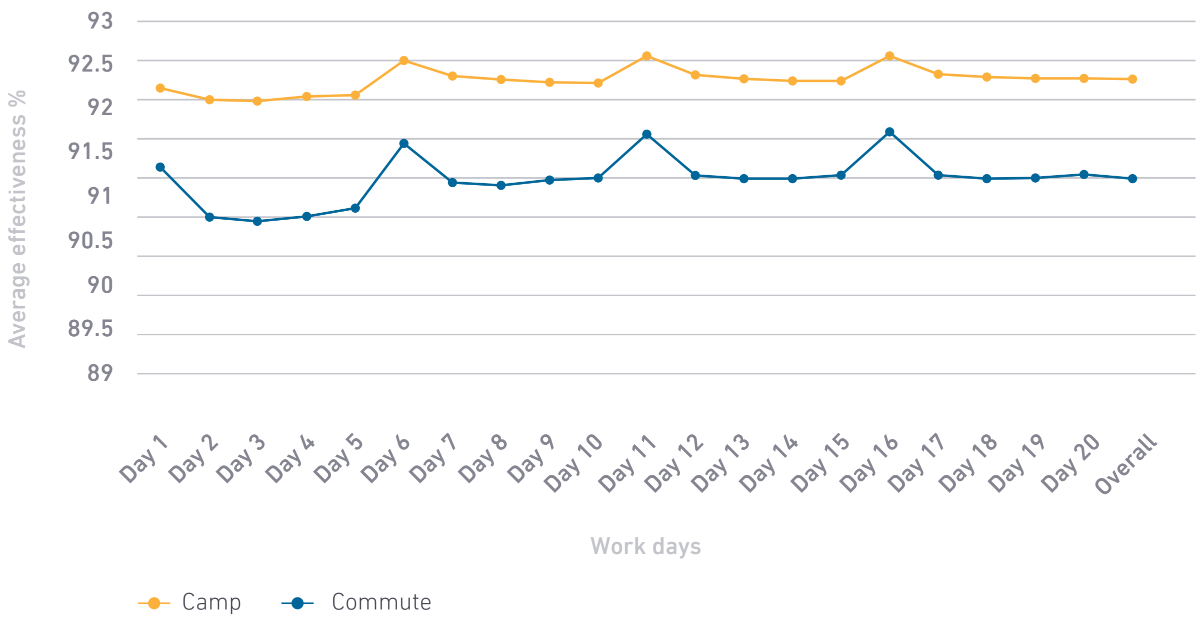


Fig. 2 - Example 24-hour period (midnight to midnight) represented by FAST curve

FAST average effectiveness % at work



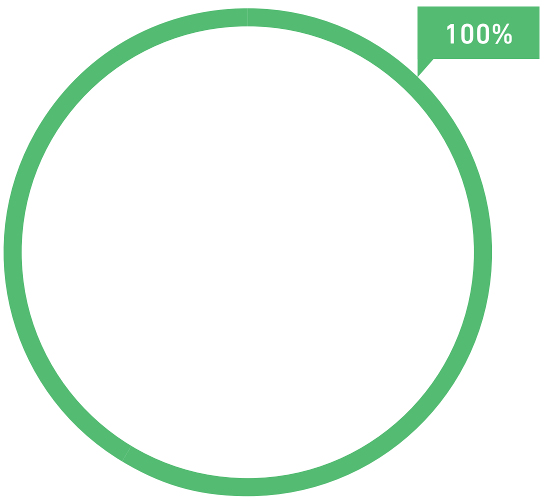
Percentage of time spent in different ranges of effectiveness

Camp

Inherent

90-100: Given the schedule design and provided workers staying in camp took full advantage of sleep opportunity (obtaining 8 hours of undisturbed sleep per night) they would be expected to be in the optimal range of effectiveness 100% of their time at work

Actual



- **90-100**: Workers staying in camp spent 100% of their time at work in the optimal effectiveness range
- Workers staying in camp spent **no time below 90** on average while at work

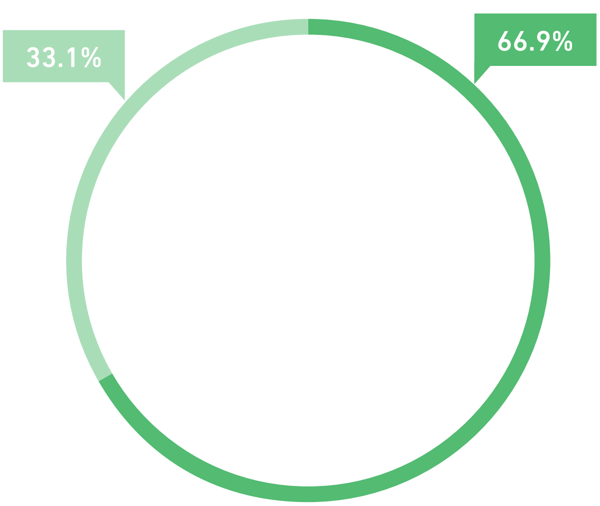
Very low (100 - 90)
Low (90 - 80)
Elevated (80 - 70)
High (below 70)

Commute

Inherent

90-100: Given the schedule design and provided workers who commute on a daily basis took full advantage of sleep opportunity (obtaining 8 hours of undisturbed sleep per night) they would be expected to be in the optimal range of effectiveness 100% of their time at work

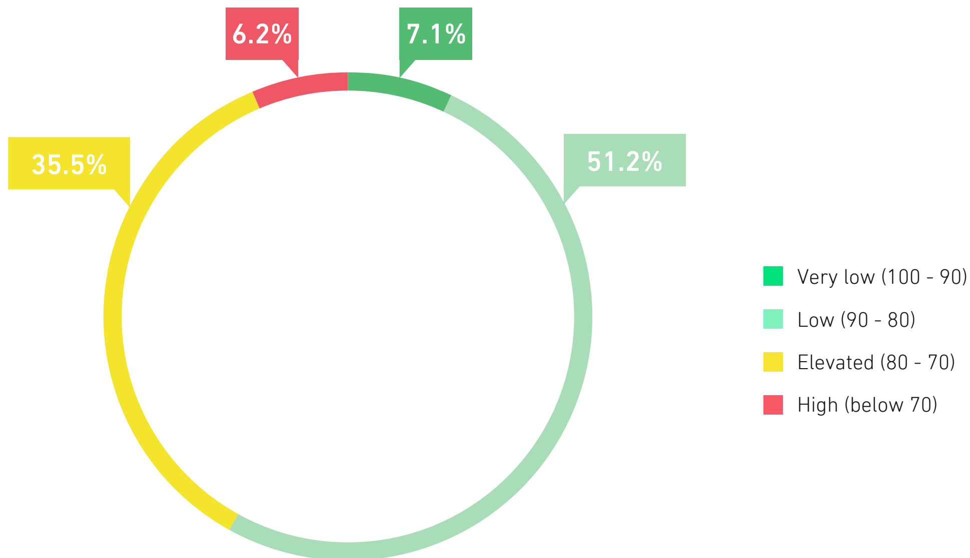
Actual



- **90-100**: Commuters spent 66.9% of their time at work in the optimal effectiveness range
- **80-90:** 33.1%
- Commuters **did not spend any time below 80** while at work, on average

Very low (100 - 90)
Low (90 - 80)
Elevated (80 - 70)
High (below 70)

In comparison, the percentage of time spent in each range of effectiveness for one of the workers whose hourly effectiveness dropped below the 70 criterion line at work would be as follows:



This worker's results generate a **11.9%** average increased accident risk.
Furthermore, there were:

- **3 out of 28 (10.7%)** camp workers who had average hourly effectiveness below 70 during work hours at least once during the study

- **4 out of 34 (11.8%)** commute workers who had average hourly effectiveness below 70 during work hours at least once during the study

FAST Potential Human Factors Accident Rating

Based on **maximum sleep** permitted by the schedule design in FAST, over the course of the 30-day schedule, workers would spend no time in a fatigue-impaired state (below the 70 criterion). Their average increased accident risk is compared to what is considered chance for workers on the job for a similar amount of time.

Potential Human Factors Accident Rating Camp	Potential Human Factors Accident Rating Commute
0% Average increased accident risk	**0%** Average increased accident risk

FAST Actual Human Factors Accident Rating

Based on **actual sleep** obtained by groups A, B and C over the course of the 30-day schedule, workers are spending on average no time working in a fatigue-impaired state (below the 70 criterion).

Actual Human Factors Accident Rating Camp	Actual Human Factors Accident Rating Commute
0% Average increased accident risk	**3.6%** Average increased accident risk

Summary of Findings

Average increased accident risk was 0% for workers staying in camps and 3.6% for those commuting, above what is considered chance for workers of similar shift duration and timing.

Notes regarding work start time, sleep opportunity and commute time:

- Workers are incurring sleep debt during their scheduled work days. If they were able to fully take advantage of their sleep opportunity during their work shifts and time off, workers could fully recover prior to commencing their next work week. Workers are waking up, on average, at 5:48 AM (camp) and 5:02 AM (commute), which contributes to sleep debt if workers are not able to maximize their sleep opportunity or optimize their sleep environment.

- Early morning start times mean workers may incur a small amount of sleep debt. Their performance during the day is split between the 80 and 100 effectiveness ranges but overall is kept above 90 on average, and well above the 70 performance effectiveness threshold.

- Workers have 2 days off prior to starting their work week , but on average, are sleeping less than 7 hours per night even on weekends. Given the short duration of time off prior to the following work week workers should take advantage of the sleep opportunity and seek to obtain a minimum of 7 to 8 hours per night.

- Those staying in camp are obtaining, on average, 12 minutes of sleep per night more than those who commute (both less than recommended 7 hours).

- Opportunity to improve on sleep quantity and quality of **camp** workers may result from assessment of sleep environment including noise, light exposure, temperature, comfort.

- Opportunity to improve on sleep quantity and quality of **all** workers may result from educational initiatives on the topic of sleep and sleep hygiene.

- Opportunity to improve on sleep quantity and quality of **some** workers may result from medical intervention.

Appendices

Appendix A- Glossary of Terms

Aggregate sleep profile

Aggregate sleep profile or data refers to the average time of day and duration of sleep periods for the overall shift roster. For the purposes of a FAST analysis, timing of sleep/wake cycles and duration of sleep periods can be obtained from Readiband sleep reports or assumed data. In instances where 'assumed' data is used, the accuracy of the FAST report metrics may vary.

Circadian Rhythm

Circadian rhythm is defined as a natural cycle of changes the body goes through in a 24-hour period. It is driven by a number of factors we cannot control, including the rise and fall of the sun. The circadian rhythm dictates that there are ideal times for our body to sleep, eat, and do activities. The hormonal and chemical changes that your body goes through in it's circadian rhythm support certain functions that you should be doing during certain phases of a 24 hour period.

Criterion or Criterion Line

The Criterion Line is a guide for using countermeasures to enhance performance and workplace safety. The significance of this measurement will depend on the nature of the work task being performed. In general, we set the criterion line at 70, which correlates to a measurable increase in workplace accident risk for those performing safety sensitive tasks. Performance Effectiveness below 70 represents the performance of a person during the day following loss of an entire night's sleep and a blood alcohol content of 0.08. (See also: Performance Effectiveness Score)

FAST graph

FAST is designed to illustrate the effects of sleep schedules on performance effectiveness by allowing the user to enter actual or hypothetical sleep schedules and view their effects based on a mathematical performance model. The Graphical View is designed to provide an easy-to-understand visual image of FAST predictions.

Lapse, Lapse Index

Lapses are excessively long reaction times associated with "micro-sleeps". Lapses increase as a linear function of the inverse of effectiveness; as effectiveness decreases, the probability of lapses increases. During an average day in a well-rested person, the lapse index averages 1.0 and ranges from about 0.2 to 1.5. A lapse index of 5 means that lapses are five times more likely than would be expected during an average day in a well-rested person. This corresponds to an effectiveness of about 70.

Performance Effectiveness Score

Fatigue Science's algorithms process sleep data (collected from Readiband or assumed data) to determine current and future cognitive effectiveness and reaction time. Fatigue Science technology reports this effectiveness score on a scale from 1 to 100. A score of 100 indicates a person or roster is fully rested and has optimized their effectiveness and reaction time. A score of 75 indicates a person or roster is less effective and has a delayed reaction time of 34%. (See also: Appendix B – FAST Performance Effectiveness Score Table)

SAFTE Model

The Sleep, Activity, Fatigue and Task Effectiveness (SAFTE™) Model is a model of sleep and performance first invented by Dr. Steven R. Hursh in 1998 and subsequently revised to reflect advances in sleep and fatigue science. This model predicts human cognitive performance based on 20 years of sleep and circadian rhythm research. The current version of the model makes valid predictions of performance under a broad range of schedule conditions, from minimal to complete sleep deprivation, at any time of day and for normal adult subjects ranging in age from the early twenties to mid-fifties. The model is homeostatic and adjusts its predictions of future performance based on the recent sleep history of the projected population or specific individuals. In the model, a circadian process influences both performance and sleep regulation. Sleep regulation is dependent on hours of sleep, hours of wakefulness, current sleep debt, the circadian process and sleep fragmentation (awakenings during a period of sleep) that reduce sleep quality. Performance is dependent on the current balance of the sleep regulation process, the circadian process, and sleep inertia.

Sleep inertia

Sleep inertia is a transitional state of lowered arousal occurring immediately after awakening from sleep and producing a temporary decrement in subsequent performance. Many factors are involved in the characteristics of sleep inertia. The duration of prior sleep can influence the severity of subsequent sleep inertia.

Appendix B- FAST Performance Effectiveness Score Table

Fatigue Science Effectiveness Score	Reaction Time Reduction (%)	Lapse Index[2]	Human Factors Accident Risk Increase[3]
100	0%	.02x	
95	5%	0.6x	
90	10%	1.5x	+11
85	17%	2.3x	
80	25%	3.2x	+14
75	34%	4x	
70[1]	43%	5.1x	+21
65	55%	6.6x	
60	64%	8.1x	+39
55	81%	9.9x	
50	100%	10x	+65

1 Researchers have determined that a score of 70 indicates an equivalent reaction time and cognitive effectiveness as an individual who has a Blood Alcohol Content (BAC) of .08.

2 Likelihood of individual or schedule roster suffering an extended lapse versus a well-rested person. For further explanation, please see the definition of 'Lapse, Lapse Index' in Appendix A.

3 Percentage increase relevant to effectiveness score is based on U.S. Department of Transportation, Federal Railroad Administration's "Validation and Calibration of a Fatigue Assessment Tool for Railroad Work Schedules, Summary Report". Statistically, if workers spend 100% of their work shift between 80-90 effectiveness they have an 11-14% increased chance of having a human factor fatigue-associated accident in the workplace.

Appendix C- Assumptions & Limitations

The Fatigue Avoidance Scheduling Tool (FAST®) is a software decision aid designed to assess and forecast performance changes induced by sleep restriction and time of day. This information is intended to help schedule planners and managers design work schedules that will reduce the risk of worker fatigue and reduce the risk of fatigue-related workplace accidents.

However, Fatigue Science warns users the predictions from this software may not be accurate for any given individual or situation. For a variety of reasons, no planning software, including FAST, can predict fatigue in all cases or for all individuals. Among the many factors that limit the ability of FAST to accurately assess fatigue in all cases are the following:

1. Management can only give the workers sufficient time to get sleep between work shifts, but cannot guarantee that the individual uses that time to get optimal sleep. FAST can only assume that the workers follow instructions to sleep and, therefore, predictions are uncertain. Even when the worker(s) take sleep, the time of day or the environmental conditions may prevent the sleep from being optimally restorative of performance.

2. Not all workers need the same amount of sleep to be optimally effective. The model assumes that all people need 8 hours of sleep per day. Any given individual may need more or less than that normative value to remain fully alert on the job.

3. Some workers may have sleep disorders that FAST cannot take into account, such as narcolepsy or sleep apnea. Some workers may use drugs or medications that alter alertness in ways that FAST cannot take into account.

4. Not all tasks require the same degree of attention. The tool currently predicts "performance of an average person on a task especially sensitive to fatigue" and may over or under estimate effectiveness of a particular person on a particular task. The tool can give the user an estimate of the range of population error, but cannot predict where a particular person falls within that range. Nevertheless, the tool makes reasonable "ordinal" predictions among schedules for most people.

5. The tool predicts departures of performance of an average person from a normal-rested "baseline". A prediction of 100 effectiveness is not error free performance; it means that performance is 100% of normal, a level that still has some risk of error.

6. The tool only predicts average performance such that steps can be taken to reduce the likelihood of error, but it cannot guarantee that for any particular individual under some specific set of circumstances, an unusual lapse in attention might occur that could, under unfavorable conditions, lead to an error, incident, or accident.

7. The tool can only forecast the effects of sleep and circadian rhythms on performance and cannot account for other factors that alter performance such as training, experience, motivation, environmental conditions, stress, boredom, illness, or any of a variety of other variables known to affect performance besides fatigue.

8. Fatigue can result from factors other than restricted sleep or circadian disruption such as excessive workload, medications, chronic fatigue syndrome, exercise, hypoxia, acceleration, temperature, or infection. These factors are not currently considered in FAST predictions.