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Work Schedules and Sleep Patterns of Railroad Signalmen

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13. ABSTRACT (Maximum 200 words)

This report presents the results of a research study designed to characterize the work schedules and sleep patterns of U.S. railroad signalmen and to examine the relationship between these schedules and level of alertness of the individuals working the schedules. The study methodology was a survey of a random sample of currently working U.S. railroad signalmen who completed a background survey and kept a daily log for 2 weeks. Signalmen are a predominantly healthy middle-aged male population. They work either construction or maintenance jobs. Both groups get the same amount of nighttime sleep, but the construction group reports better sleep quality and better daytime alertness. This difference is likely due to the unscheduled work periods and nighttime calls that maintenance jobs entail, as well as the start time variability of maintenance jobs. During the study period, nearly two-thirds of the maintenance signalmen had at least one unscheduled work period. Over 50 percent of signalmen get less than 7 hours of sleep on work nights, while 39 percent of U.S. adults get this amount. Possible explanatory factors for daytime alertness levels, including time without a break, total hours worked, and commute time, were explored. Based on the experience of this study, several methodological changes are suggested for future studies of this type.

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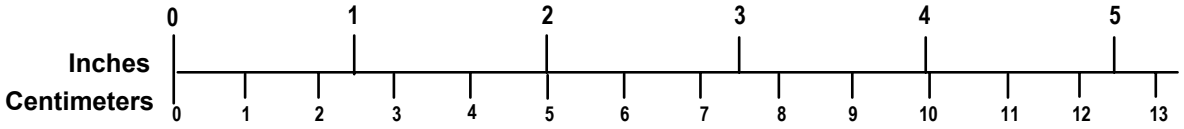

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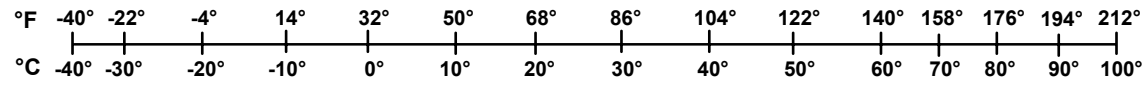

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This report presents the results of a research study designed to characterize the work schedules and sleep patterns of U.S. railroad signalmen and to examine the relationship between these schedules and level of alertness for the individuals working the schedules. Foster-Miller, Inc. conducted the work for the Federal Railroad Administration (FRA) under contract DTFR53-01-D-00029 with guidance from Dr. Thomas Raslear, Office of Research and Development, Human Factors Program. The authors worked closely with the Brotherhood of Railroad Signalmen (BRS) in designing and conducting this survey. Special thanks are due to Mr. Tim DePaepe and Mr. Kelly Haley, BRS, who provided invaluable insight on the job of a signalman and facilitated distribution of the survey materials to their members. Their participation was a key element in the successful conduct of the study. The authors are especially appreciative of the efforts of Mr. Robert Brogan, FRA Office of Safety, who facilitated the Office of Management and Budget approval process for this study.

The authors also wish to thank several individuals at Foster-Miller for their significant contributions to this survey. Ms. Susan McDonough designed and managed the database for tracking and compensating the survey participants. Ms. Sarah Acton answered questions from survey participants and also helped to review the log books before the data was coded. Ms. Gayle Staffiere from Foster-Miller's Publications Department was responsible for layout of the log books and oversaw printing and mailing of the survey documents. Ms. Jeanne Seaquist designed the database for the survey data, and Ms. Deidra Bradley entered data from the background survey and log books into the database.

Executive Summary

In a continuing effort to improve rail safety and to reduce the number of injuries and fatalities to railroad workers, the Federal Railroad Administration (FRA) and the railroad industry, through the North American Rail Alertness Partnership (NARAP), have focused on the issue of fatigue among train and engine crew personnel. Because railroading is a round-the-clock, 7-days-a-week operation, and because a wide array of workers are needed both to operate and to maintain the nation's railroads, other crafts besides train and engine crews may also be subject to fatigue. The non-operating crafts, which include locomotive and car repair, right-of-way construction and maintenance, signal system construction and maintenance, and telecommunications, fall into this category. With all of the non-operating craft groups, staff shortages, seasonal work, expanding territories, and response to emergency situations can result in long work hours leading to fatigue. In 2001, FRA suggested and NARAP concurred, on the need to study the fatigue issues of the non-operating crafts. FRA decided to focus initially on signalmen.

The intent of the Hours of Service Law, which applies to signalmen, is to reduce fatigue and ensure that signal employees are well rested when performing their safety sensitive duties by limiting daily work hours. Situations arise, however, where the provisions of the Hours of Service Law are extremely deficient in guaranteeing an adequately rested work force. Emergency provisions allow railroad signalmen to work up to 16 h a day.

This study had two primary objectives:

- To document and characterize the work/rest schedules and sleep patterns of signalmen.
- To examine the relationship between these schedules and level of alertness/fatigue for the individuals who work the schedules.

The goal was to characterize U.S. signalmen as a group, not to characterize signalmen on a specific railroad.

The research described in this report had three phases: preparation, field data collection, and data analysis. Since no existing data source would provide answers to the study's research questions, a survey of signalmen was the only means to obtain the necessary data. The preparation phase included securing approval from the Office of Management and Budget (OMB) for the survey. Representatives from the Brotherhood of Railroad Signalmen (BRS) worked closely with the researchers throughout the study.

Survey Design

The study used two survey instruments, a background survey and a daily log. Survey participants used the background survey to provide demographic information, descriptive data for the signalman's job type and work schedule, and a self-assessment of overall health. The daily log provided a place to record sleep and work periods on both regular workdays and planned days off. Signalmen recorded not only the starting and ending times for each sleep and work period, but also a subjective assessment of alertness at different times during the day. To capture the work cycle of the construction signalmen, it was necessary to collect 14 d of work and sleep data.

A random sample of 819 signalmen was drawn from the BRS database of actively working U.S. signalmen. Retirees, full-time union officials, and anyone currently holding a railroad management position were specifically excluded from the sampling frame. Determination of the sample size assumed a 95 percent confidence level on the estimates for mean sleep time, an error tolerance of 15 percent, and a 40 percent response rate. OMB approved this collection of information under OMB control number 2130-0558 on October 2, 2003.

Mailing of the survey materials occurred on October 16, 2003. One month later, every survey recipient received a reminder postcard encouraging him/her to participate and to call the researchers if he/she needed additional materials.

Survey Response Rate

The overall response rate for the survey was 49.9 percent. Table 1 provides a breakdown of the survey responses.

Table 1. Breakdown of survey responses

	Number	Percent
Returned both background survey and daily log	409	49.9
Returned only one survey instrument	10	1.2
Materials undeliverable due to invalid address or deceased	6	0.7
No response	394	48.1
Total number of surveys mailed	819	

Of the 409 complete responses, 6 were not usable due to failure to follow the instructions, and 14 were not eligible because they were from telecommunications workers and not signalmen. (It was not possible to identify and remove these people *a priori*.)

The non-response bias study based on participant age found no difference between respondents and non-respondents.

Signalmen Demographics

The survey respondents held primarily maintenance jobs (65 percent) and construction jobs (29 percent). The remainder worked yard maintenance. Average signalman experience was approximately 18 yr, but construction signalmen had 7 yr less experience than non-construction signalmen. The majority of signalmen are middle-aged with over 70 percent being 40 yr and older. The average age for construction and non-construction signalmen differed by 4 yr with non-construction signalmen being older. All but three participants were male so segregation of the survey results by sex was not meaningful.

Nearly all signalmen (85.3 percent) were married with no children under the age of 2 yr. In contrast, 58.9 percent of the U.S. male population 18 and older is married. Since many railroaders report that their work schedule strains marital relationships, finding such a high proportion of signalmen to be married was surprising. The lack of young children is consistent with the average age of this population.

Over 86 percent of the signalmen reported their health as good or excellent. More than 84 percent had not taken a day off due to illness in the last 6 mo. The low number of workdays lost due to illness may be due in part to the fact that signalmen are not compensated for sick days.

Approximately 6 percent of the signalmen reported having a diagnosed sleep disorder, and almost one third of those have gone without treatment. Since the survey asked about a diagnosed sleep disorder and not sleep apnea specifically, this result cannot be compared directly with the estimate of the prevalence of sleep apnea in the U.S. adult male working population. The true rate of sleep disorders may be higher, as some may have an undiagnosed sleep disorder.

Job Characteristics

The work schedules of construction and non-construction signalmen differ in several respects. While both types of jobs normally work 80 h in a 2-week period, nearly all non-construction jobs (96 percent) have a 5-d work week, but less than a quarter of the construction jobs have this schedule. Half of all construction jobs work a 4-d week, and 26 percent work 8-on 6-off.

During the 2-week survey period, non-construction signalmen worked 87:32, and the construction signalmen worked 83:16. For both groups of signalmen, this was less than they reported typically working but more than their nominal schedules dictate. The difference between the two groups was likely due to emergency calls and other unscheduled work that non-construction signalmen must handle. Comparison of the survey results with the 2002 average straight time equivalent (ASTE) hours for signalmen indicated that the survey period was one of lighter than normal workload.

Over a third of non-construction signalmen experienced start time variability at least once during the survey period, most likely as a result of an emergency call or unscheduled work. (The definition of start time variability was a change in start time of more than 1 h from the previous day.) In contrast, 90 percent of the construction signalmen experienced no start time variability.

Nearly two-thirds of the non-construction signalmen (63.9 percent) had at least one unscheduled work period in the 2-week period of the study. This group averaged 1.9 unscheduled work periods. On any given day, the probability of an unscheduled work period was .12. Once called for an unscheduled work period, a signalman had a 14 percent chance of being called back a second time. An unscheduled work period on a work night affected next day morning alertness; however, the effect size was somewhat small.

The study examined the relationship between other characteristics of the signalmen's work schedules and alertness. The characteristics examined included time without a break, total hours worked, and commute time. While the correlations between alertness and these factors were significant, the strength of the relationships were weak. For example, there was a correlation coefficient of -.179 between time without a break and alertness upon arriving home, but $r^2 = .032$. This means that the time without a break explains only 3.2 percent of the variance in alertness upon arriving home.

Sources of work-related stress were different for the two groups of signalmen. Only in the case of travel to work did construction signalmen report a statistically different and higher level of stress than their non-construction counterparts. On call schedule, emergencies, and sleep loss were all statistically different and greater sources of stress to non-construction signalmen.

Sleep Characteristics

Signalmen get less nighttime sleep than U.S. adults on both workdays and planned days off. While 39 percent of U.S. adults get less than 7 h of sleep on workdays, over 50 percent of signalmen have this amount of sleep. Total daily sleep, which includes naps as well as nighttime sleep, for construction and non-construction signalmen is about 1 h longer on planned days off than on workdays. Naps on planned days off are slightly longer than on workdays. Nearly half of all naps begin between 2 and 6 p.m., which corresponds with the circadian afternoon nadir, making it a convenient time for naps. This time period also follows the end of the workday for many signalmen.

While both groups of signalmen get about the same amount of daily sleep, construction signalmen rated their sleep of higher quality than the non-construction group on both workdays and planned days off. This is likely due to disrupted sleep resulting from nighttime emergency calls that the non-construction group must handle. Both construction and non-construction signalmen gave higher ratings to their sleep on planned days off than on regular workdays. Construction signalmen rated their work night sleep at home of higher quality than the sleep they get when away from home, although the duration of their nighttime sleep is shorter at home.

Signalmen with diagnosed but untreated sleep disorders rated their sleep of lower quality and had lower alertness ratings throughout the day than those with treated sleep disorders or no sleep disorders.

Textual Analysis of Log Book Comments

A systematic qualitative analysis of the textual comments in the daily logs provided greater insight into the concerns of signalmen and in many cases, added further insight to the quantitative survey results. Over 2000 comments were in the log books. The two most frequently mentioned topics were fatigue (i.e., physical fatigue, being sleepy, feeling worn down) and unscheduled work.

Findings and Recommendations

The key findings with respect to the signalmen's nominal work periods, unscheduled work periods, and sleep patterns are the following:

- While the average hours worked during the study period do not indicate excessive overtime, one quarter of the construction signalmen worked at least 1 d of overtime, and one quarter of the non-construction signalmen worked at least 1.5 d of overtime.
- The overall signalman workday allows adequate time for nighttime sleep. The nighttime call of non-construction signalmen, however, likely prevents them from getting adequate and restful sleep when they are called.
- The variability of the non-construction signalman's work schedule is likely responsible for their lower alertness levels throughout the work day.
- Unscheduled work periods were responsible, to a limited degree, for lower alertness the following morning.
- Both groups of signalmen get less nighttime sleep during the work week than the norm for U.S. adults. Not only is weeknight sleep significantly different than the U.S. norms, but the percentage of signalmen getting less than 7 h or sleep is also significantly greater

than the norm for U.S. adults. A total of 16 percent are getting less than 6 h of nighttime sleep, and 1.8 percent are getting less than 5 h. Research has shown that this level of sleep deprivation leads to performance degradation. Railroad industry and labor organizations' fatigue education programs should emphasize the performance consequences of inadequate sleep.

- While both groups of signalmen get the same amount of sleep, the non-construction group rates their sleep of lower quality, likely due to start time variability and unscheduled work periods.
- Six percent of the study population reported having diagnosed sleep disorders. Comparison of those with treated versus untreated sleep disorders revealed that those with untreated disorders got poorer sleep and reported lower alertness levels throughout the workday. To encourage these individuals to seek treatment, railroads and unions should continue their education programs, pointing out the possible performance consequences of untreated sleep disorders.

Based on the experience of this study, several methodological changes should be a part of any future studies of this nature. The following lists the recommended changes:

- If the study population includes workers who must travel long distances on their own time to reach the rally point or lodging site, the daily log should have a place to enter this data.
- The background survey should inquire whether or not the respondent has been diagnosed with sleep apnea, as well as a sleep disorder, so that the results can be compared with U.S. norms for sleep apnea.
- If possible, data collection should occur at a time of year that has a typical workload.
- The data collection period should avoid daylight savings time changes and holidays.
- Future studies should include explicit instruction to not collect data during a vacation period.

Further analysis and use of this survey data is possible. Fatigue modelers may want to refine their models using the data and predict how the typical signalman's work schedule may be affecting on-the-job alertness and related performance. In addition, further statistical analysis of the data could identify additional explanatory factors for the reported alertness levels and sleep quality.

1. Introduction

In a continuing effort to improve rail safety and to reduce the number of injuries and fatalities to railroad workers, FRA and the railroad industry, through NARAP, have focused on the issue of fatigue among train and engine crew personnel. Because railroading is a round-the-clock, seven-days-a-week operation, and because a wide array of workers are needed both to operate and to maintain the nation's railroads, other crafts besides train and engine crews can also be subject to fatigue. The non-operating crafts, which include locomotive and car repair, right-of-way construction and maintenance, signal system construction and maintenance, and telecommunications, fall into this category. With all of the non-operating craft groups, staff shortages, seasonal work, expanding territories, and response to emergency situations can result in long work hours, leading to fatigue. In 2001, FRA suggested and NARAP concurred on the need to study the fatigue issues of the non-operating crafts.

FRA decided to focus initially on signalmen in exploring fatigue of the non-operating craft workers. Although the Hours of Service Law limits daily work hours for signalmen, the regulatory limits do not guarantee an adequately rested work force. Emergency provisions allow railroad signalmen to work up to 16 h a day. Hours of Service records, which are required to be kept by railroads, include only the actual hours worked. They do not document sleep periods. Obtaining insight into the schedule-related fatigue issues of any population of workers requires data on both their work and sleep patterns. FRA undertook the study described in this report to collect the necessary data and to develop an understanding of the potential work schedule-related fatigue issues for signalmen.

1.1 Nature of the Signalman's Job

In the past decade, the volume of shipments of goods by rail increased significantly, while the railroad work force declined. In 1990, the volume of goods transported by railroads amounted to 1.1 trillion ton-miles. By the year 2000, the volume of goods carried by railroads totaled 1.5 trillion ton-miles. Meanwhile, the number of railroad signalmen working for U.S. railroads decreased from 9,382 to 8,552, or 9 percent, during the 4-yr period 1999 to 2003. Concurrent with the increase in freight shipments, the number of signalized crossings also increased, from 58,222 in 1995 to 61,980 by the end of 2001. Both of these factors have led to a greater workload for railroad signal departments and the people who perform the work.

Additional safety regulations, while contributing to a reduction in accidents/incidents and injuries involving railroad workers, have also increased the workload of signalmen. The Roadway Worker Protection regulations, effective since January 1997, have helped to reduce accidents and injuries to railroad workers in the vicinity of the right-of-way, but the procedures necessary to achieve this level of safety have lengthened roadway workers' time on the task. Additionally, since January 1995, extra testing is required before a grade crossing signal system can be put into service. This too has intensified demands on railroad signalmen.

Signalmen work two fundamental types of jobs: maintenance and construction. Signal maintainers are responsible for inspecting and certifying the functioning of the signal and communication equipment on a specific track territory. The maintainer is also responsible for making minor repairs as s/he inspects. Depending upon the railroad, a separate gang of maintainers may be responsible for repairs that cannot be done in the course of the routine

inspection. The job of a maintainer has a regular daily schedule, but the maintainer is also subject to call for emergencies at night and on weekends. Major yards also have maintainers permanently assigned to maintain the signal system in the yard. These individuals work on a shift work schedule to cover the yard around the clock. Most signalmen work on wayside signal equipment, but a limited number work on communications equipment, such as radios and antenna systems.

In contrast to the maintainer, a signalman who works on a construction gang will usually work a compressed schedule of, for example, 8 workdays followed by 6 d off and is rarely called for an emergency. Maintainers work in a defined geographic area. In contrast, signalmen on a construction gang can work anywhere on the railroad's system and likely travel long distances, on their own time, to reach the construction sites.

An individual new to this craft will be hired on as an assistant signalman. The first 2 yr on the job include 2 weeks of signalman school every 6 mo. The average assistant signalman qualifies as a signalman after 2 yr on the job.

Since 1976 the Hours of Service Law for railroad workers and the associated FRA regulations (49 C.F.R. § 228) have applied to a railroad employee "engaged in installing, repairing or maintaining signal systems." This law provides that after working 12 consecutive h, in a 24-h period, a signalman must have at least 10 consecutive h off before being permitted to return to work. If the employee works less than 12 h in a 24-h period, then s/he must have at least 8 h off before returning to duty. However, if an employee works up to 12 non-consecutive h during a 24-h period, the employee must have at least 8 consecutive h rest before returning to duty. The law includes an emergency provision that permits employees to stay on duty up to 16 h if extraordinary circumstances necessitate continued service. Such instances must be reported to FRA, and the burden of proof rests with the carrier to establish that the excess service could not have been avoided.

Signal maintainers are responsible for responding to emergencies at night and on weekends. Depending upon the nature of the territory, signal maintainers may have an on-call schedule, but more commonly they are responsible for all emergencies in their territory. When a signalman is on call to respond to emergencies after the normal workday, s/he is not compensated for handling problems over the phone; however, if s/he must travel to the work site, the travel time is on the clock. When an emergency call comes, if the signalman has not worked 12 h, s/he may report back to work to handle the emergency.

While the intent of the Hours of Service Law is to reduce fatigue and ensure that signal employees are rested when performing their safety sensitive duties, situations arise where the provisions of the Hours of Service Law are extremely deficient. For example, a signal maintainer goes to bed at 10 p.m. on a Sunday night and gets up at 5 a.m. to report to duty on Monday morning. S/he works the regular shift from 7 a.m. until 4 p.m. The mandatory rest period begins at 4 p.m. and ends at 12 a.m. Tuesday morning. Under the Hours of Service Law, s/he is considered fully rested at this time. At 12:30 a.m., s/he is called for duty. Being fully rested at 12 a.m., according to the regulations, a new 24-h work period begins at 12:30 a.m., the time of the trouble call. The signalman can now work 12 consecutive h, possibly up to 16 consecutive h if it is an emergency. While under the law s/he is considered fully rested, the reality is that after being released from work at 12:30 p.m. on Tuesday, or 4:30 p.m. in the case of working 16 consecutive h, the employee likely has slept for not more than 2 or 3 h over the

past 31.5 h or 35.5 h. In either case, this individual will be suffering from sleep deprivation and is more likely to make a mistake in performing his/her duties.

1.2 Objectives

This study had two primary objectives:

- To document and characterize the work/rest schedules and sleep patterns of signalmen.
- To examine the relationship between these schedules and level of alertness/fatigue for the individuals who work the schedules.

The goal was to characterize U.S. signalmen as a group, not to characterize signalmen on a specific railroad or in a particular region of the country.

Specific research issues that the study was designed to answer include the following:

- What is the distribution of signalmen among different types of jobs?
- What is the average number of hours worked per day? per week? per work cycle[1] (for work cycles longer than a week)?
- How does average hours worked vary by type of job?
- What is the average hours slept on workdays? on non-workdays? at home? away from home?
- Does the quality of sleep differ between home and away from home?
- Does alertness upon arising deteriorate with each successive workday?
- What is the relationship between time worked before a break in work period and end of workday fatigue?
- What is the average number of hours that each signalman spends traveling to and from work? Is travel time related to level of alertness?
- How frequently are signalmen called back to respond to emergencies?

1.3 Overall Approach

Since no existing data sources would provide answers to the above issues, a survey of signalmen was the only means to obtain the necessary data. This research project consisted of three phases: preparation, field data collection, and data analysis (see Figure 1). The preparation phase involved designing the survey methodology and procedures, conducting a pilot survey to refine the survey instruments and data collection procedure, securing approval from the OMB, and preparing the final survey instruments. (Because this survey involved more than nine participants, Federal regulations required that OMB approve the overall study design.) Activities during this phase included discussions with the BRS to assure that the survey instruments had suitable wording and would collect appropriate data to answer the research issues. A pilot

[1] A work cycle refers to several workdays followed by planned days off.

survey, conducted in parallel with the OMB review process, assured that the survey would capture the data needed to meet the survey objectives.

The second phase of the research consisted of distributing the survey materials and collecting the survey data. Analysis of the survey data was the final phase. A non-response bias study validated that no difference existed between the survey participants and the non-respondents. The data analysis methods for the survey data included descriptive statistics, analysis of variance (ANOVA), and correlation analysis.

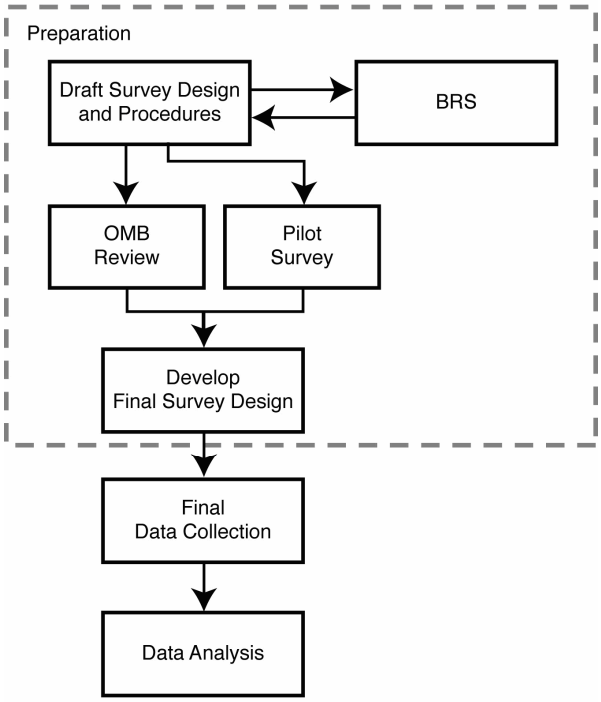

Figure 1. Overall approach

1.4 Scope

This survey involved signalmen actively working in the United States. It was designed to characterize all signalmen as a group. The study was not designed to characterize signalmen working for specific railroads. Making specific recommendations regarding fatigue countermeasures was beyond the scope of this study.

1.5 Organization of the Report

Section 2 describes the overall survey design and procedures. Analysis of the survey results is in Section 3, and Section 4 contains the findings and recommendations. Section 5 contains a list of references. Appendix A contains copies of the survey materials, and Appendix B describes adjustments that were made to the data as part of the analysis process. A list of abbreviations follows the appendices.

2. Survey Design

One of the objectives of this study was to characterize the work and sleep patterns of U.S. signalmen. Achieving this objective required a nationwide survey. The only practical means of reaching these individuals was through their union, BRS. This section describes the survey instruments, sampling plan, and procedures that were developed to survey this population.

2.1 Survey Instruments

The study used two survey instruments, a background survey and a daily log. (Copies of both instruments appear in Appendix A.) The background survey gathered demographic information, descriptive data for the signalman's job type and work schedule, and a self-assessment of overall health. The purpose for collecting this data was twofold. First, it provided data for characterizing the U.S. signalman population. Second, it provided identifying data that was used in conjunction with the daily logs to characterize the work/sleep patterns of the two major categories of signal jobs, maintenance and construction. This instrument also asked participants to rate, using a Likert scale of 1-4, potential sources of stress at work. A list of life stress events was also a part of the background survey. In the event that a participant's daily log indicated frequent nighttime awakenings or excessive fatigue, the individual's response to this section of the background survey could be used to assure that no non-work circumstances were confounding the survey data. Completion of the survey required less than 15 min.

A daily log provided a place to record sleep and work periods on both regular workdays and planned days off. Signalmen recorded not only the starting and ending times for each sleep and work period, but also a self-assessment of alertness at different times during the day. These subjective assessments used a Likert scale. The daily log included space to record "Comments on today's sleep experience" and "Comments on today's work experience." The instructions for the log encouraged participants to use this space to explain anything unusual about the day's sleep or work. These comments proved useful in understanding an irregular work or sleep pattern. The work log portion of the daily log included space to record unscheduled work periods. This section captured data for response to emergency calls beyond the normal workday.

2.2 Data Collection Period

Examination of the relationship between work schedules and fatigue requires data that includes a full work cycle. Fatigue is cumulative, and its effects on the individual are not readily identified from 1 or 2 d of data. In addition, adequate data must be available to compare sleep periods from both work and rest days. The length of the typical signalman's work cycle was also a consideration in determining the length of the data collection period. Signal maintainers tend to work a regular work week of 4 or 5 d followed by 2 or 3 d off. In contrast, those working construction jobs tend to have a 14-d compressed work cycle. To capture the work cycle of the construction jobs, it was necessary to collect 14 d of work and sleep data. Since it was not possible *a priori* to identify those signalmen who work a construction job, all participants provided 2 weeks of data.

2.3 Sampling Plan

BRS maintains a database with the names, mailing addresses, and date of birth for all of its members. Because signalmen frequently change from working one type of job to another, this information is not in the BRS database. Only actively working BRS members living in the United States were included in the sampling frame. Retirees, full-time union officials, and anyone currently holding a railroad management position were specifically excluded. The BRS membership includes a small number of telecommunications workers. Since the Hours of Service Law does not apply to these people, it was preferable to exclude them from the sampling frame. Unfortunately, no way existed to identify them *a priori*. The effective sampling frame was 8,241 after the exclusions were made. Respondents were selected randomly from this sampling frame.

One of the most important issues in conducting this study was determining how large a sample was necessary for the estimates obtained in the sample survey to be reliable enough to meet the study's objectives. In general, the larger the sample the greater the reliability of the resulting estimates, but this must be traded off against the expense of a larger sample. The first step in this process was to specify the level of reliability needed for the resulting estimates.

The purpose of this study was to obtain descriptive information about work hours, sleep, and level of alertness. FRA felt that 95 percent confidence was adequate for this purpose. In addition, FRA determined that the estimate should be within 15 percent (±7.5 percent) of the true value. This error level is consistent with the known variance of daily sleep in the general population (Webb, 1992). Since a majority of the study results involve proportions, the sample size must be adequate to assure that the proportion estimates–for example, the fraction of signalmen who are maintainers–are within 1.96 standard deviations of the true population proportion. The appropriate sample size, n, can be calculated from the following:

$$n \geq \frac{z^2 N P_y (1 - P_y)}{(N-1)\varepsilon^2 P_y{}^2 + z^2 P_y (1 - P_y)}$$

where z = reliability coefficient (1.96 for 95 percent confidence level)

N = population size (8,241)

P_y = unknown population proportion (.6)

ε = error tolerance (.15)

Signalmen work two fundamental types of jobs: maintenance and construction. Because both the nature of these jobs and their work schedules differ, this study must characterize each type of job separately. BRS estimated that approximately 60 percent of signalmen work as maintainers and the remainder work construction jobs. Evaluating the above formula for a 95 percent confidence level and an error tolerance (ε) of .15, the study must have at least 112 participants to estimate the proportion of signalmen working maintenance jobs.

Since the study design includes examining characteristics of subgroups of signalmen (maintenance versus construction), the study design must assure that the subgroups have

adequate numbers within the overall sample to support reliable estimates of their characteristics. One statistic of interest is mean number of hours of sleep per day for each subgroup. Using the BRS estimate of the workforce breakdown, approximately 4,946 maintainers and 3,295 construction signalmen are in the sampling frame. The appropriate sample size, n, for estimating the mean daily sleep time can be computed from the following:

$$n \geq \frac{(z^2 N V_x^2)}{z^2 V_x^2 + (N-1)\varepsilon^2}$$

where z = reliability coefficient (1.96 for 95 percent confidence level)

N = population size

V_x = unknown population variance (1)

ε = error tolerance (.15)

Webb (1992) estimates that the standard deviation for daily sleep for the general population is 1 hour (Webb, p. 72). Applying this estimate of standard deviation (and hence V_x, variance) to the two signalman subpopulations and using an ε = .15, 165 maintainers must be in the sample, as well as 162 construction signalmen, or a total of 327 participants. This estimation for sample size applies to other mean values, such as work and commute time, that the study seeks to estimate.

Since not every BRS member who is selected to participate in this study would choose to do so, oversampling was necessary. The extent of oversampling is a function of the anticipated response rate. A recent BRS survey of its members had a 40 percent response rate (personal communication with BRS representative). The study design reflected the conservative assumption that the planned study could likely achieve at least this response rate. Based on experience with other FRA research efforts that sought participation from railroad workers, FRA researchers have found that many are suspicious of any efforts to collect data, even if the effort has the endorsement of their labor union and the researchers assure the confidentiality of the information. Moreover, this survey differs significantly from most mail surveys in that it required responses every day for a 14-d period. For these reasons, the goal of a 40 percent response rate appeared reasonable and realistic. If 40 percent of the selected individuals agreed to participate in the study, then the random sample must be 819 (327/.4) to yield 327 participants.

2.4 Procedure

In accordance with government regulation, FRA sought approval for the proposed survey from OMB. OMB approved this collection of information under OMB control number 2130-0558 on October 2, 2003.

Concurrent with submittal of the OMB application, a 1-week pilot survey with nine participants was conducted to refine the data collection procedures and instruments. In addition to completing the Railroad Signalman Background Survey, and Signalman's Daily Log, pilot participants also completed a brief Post-Survey Form to provide feedback on the survey

instruments and procedures. Similar to the full survey, pilot participants received a $75 gift certificate to a national retail establishment. Based on the experience with the pilot survey, several additional Sources of Stress were added to the Background Survey and wording in the "Your Work Schedule" section of this instrument was modified. A change was also made in the layout of the Likert scales in the Daily Log. Following the pilot survey, during spring 2003, BRS publicized the survey through an article in its publication, *Signalman's Journal,* and on its Web site.

A simple random sample of 819 signalmen was drawn, without replacement, from the sampling frame derived from the BRS membership list. The package mailed to each participant on October 16, 2003, consisted of the following items:

- *Railroad Signalman Background Survey* in booklet form. Each page was 5.5 x 8.5 in, printed on white paper with no questions on the cover page.
- *Signalman's Daily Log* in spiral notebook form. Each page was 5.0 x 3.25 in. There were 14 sections, one for each day of the data collection period. One of the introductory pages contained brief instructions on completing the log.
- *Cover letter* signed by the President of BRS. This letter explained the purpose of the study and encouraged BRS members to participate.
- *Instructions* explaining the survey procedures and how to complete the daily log.
- *Return envelope,* postage paid.
- *$5 bill.*

Copies of the cover letter and instructions appear in Appendix A along with the survey instruments.

All materials were printed on high quality paper, and each letter was individually addressed to the recipient. The mailing envelope used the BRS return address, rather than Foster-Miller, because it would be familiar to recipients. The purpose of the $5 bill was to encourage participation. Those who returned both the background survey and daily log also received a $75 gift certificate to a national retail establishment.

The instructions emphasized that (1) a total of 14 consecutive d of data should be provided and (2) data collection should begin on the first day of the next work cycle. Both the instructions and the log included contact information for two Foster-Miller researchers who were available to answer questions regarding the survey instruments and procedures.

One month after the mailing of the materials, every survey recipient received a reminder postcard encouraging him/her to participate and to call Foster-Miller if he/she needed additional materials.

3. Analysis of Survey Data

This chapter presents the survey findings based on data provided in respondent background surveys and daily logs. The quantitative results are organized into five subtopic headings:

- Survey response rate
- Non-response bias study
- Signalmen demographic characteristics
- Job characteristics
- Sleep patterns

A separate subsection presents the results of a textual analysis of the log book comments.

This study used a confidence interval of 95 percent. The researchers used SPSS 11.5 to analyze the data.

3.1 Survey Response Rate

The survey materials were mailed to 819 signalmen. A total of 409 people returned both the background survey and the daily log. The remainder, 410, includes 394 individuals who chose not to participate, 10 who returned only one of the survey instruments, and 6 whose materials were returned as undeliverable due to an incorrect address. The overall response rate for the survey was 49.9 percent.

Of the 409 complete responses, 6 were not usable due to missing data or failure to follow the instructions for recording information in the daily log, and 14 more were not eligible because the participants were telecommunications workers and not signalmen. It was not possible to identify in advance those BRS members in telecommunications jobs so that they could be eliminated from the sampling frame. This left a total of 389 responses that were used in the analysis. If a log contained at least one work cycle of data for both workdays and planned days off, then the data was included in the analysis.

3.2 Non-Response Bias Study

OMB requires that a non-response bias study be conducted if the survey response rate is below 75 percent. The purpose of the non-response bias study is to assure that no difference exists in the characteristics of the survey respondents versus the non-respondents.

Information about non-respondents was limited to information available in the BRS membership database. In addition to each member's address, this database includes birth date. Birth date (or age) is an appropriate variable to use for determining non-response bias. For a number of reasons, age is an important characteristic for assessing potential bias in this study. First, human sleep patterns change with age. In addition, age is highly correlated with years of work experience and seniority. Seniority allows a signalman more opportunity to select work schedules that meet his/her personal needs.

All 409 individuals who returned both the background survey and the log were respondents and the remaining 410 were non-respondents. Both the respondent and non-respondent groups were divided into two age groups: (1) age 43 and younger and (2) age 44 and older. This age breakdown corresponds to that used in a recent study that examined age-related changes in sleep of healthy men (Van Cauter, Leproult & Plat, 2000).

The BRS database did not contain birth date information for 14 people so only 396 of the 410 non-respondents could be included in the non-response bias study. Analysis of the mean age for each of the two age subgroups found no significant difference between the respondents and the non-respondents, for 43 and under: $t(351) = -.808$, $p = .420$ and for 44 and over: $t(450) = .098$, $p = .922$.

3.3 Signalmen Demographic Characteristics

This section provides demographics, as well as basic job-, family-, and health-related information based on responses in the background survey. Where appropriate, the study results are compared with national norms.

Characterizing the signalmen considered a number of factors. These factors are job type, work experience, sex and age, marital and family status, overall health, incidence of sleep disorders, and consumption of caffeinated beverages. Each of these elements is discussed below, followed by a brief summary of this information.

3.3.1 Job Type

The background survey asked respondents to report the type of signalman job they worked and offered four options from which to choose: Construction, Maintenance (other than yard), Yard maintenance, and Other. Eighteen signalmen selected Other as their job type and gave a brief description of their jobs. With assistance from a BRS representative, 15 of these individuals were re-categorized as maintenance (other than yard) and two as construction. Three remained in the other category.[2]

Figure 2 displays the distribution of signalmen job types from the survey. A majority of signalmen, 65 percent, worked maintenance jobs, while 28.5 percent worked construction jobs. Yard maintenance (5.7 percent) and other (0.8 percent) accounted for the remainder of the group. For computation of the sample size for this study, BRS estimated that 60 percent of signalmen hold maintenance jobs. Seasonal variations cause this proportion to shift throughout the year so the difference between the expected and survey values is not problematic.

Because construction jobs tend to have different work schedules and are rarely subject to emergency call, all further analyses by job type compare construction jobs with all non-construction jobs. Non-construction includes maintenance, yard maintenance, and other.

[2] One reported a trainer job, one was an equipment room maintainer, and the third did both construction and maintenance.

3.3.2 Experience

The average signalman had 18.1 yr experience; however, a significant difference existed in the level of experience between construction and non-construction signalmen, $t(387) = -6.032$, $p < .05$. Those working construction jobs had an average of 12.9 yr experience, while the non-construction signalmen had 20.2 yr experience. The median value for years of experience for construction signalmen is lower than the mean for this group, indicating that less experienced signalmen work these jobs, but a few had many years of experience, raising the group mean. In contrast, the median experience for non-construction people was higher than the mean for this group, indicating that more experienced signalmen prefer these jobs, but a few relatively junior people brought the mean down (see Table 2).

Signalmen working construction jobs had nearly all of their experience with their current employer, while those working non-construction jobs had several years' experience before signing on with their current employer (see Table 3).

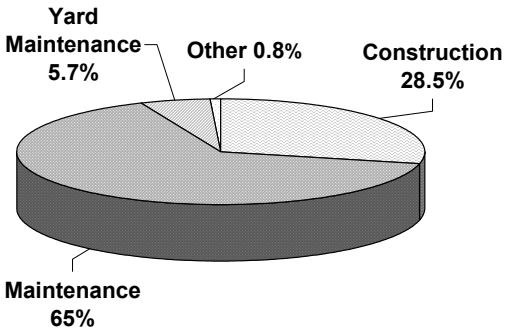

Figure 2. Distribution of respondents by type of signalman job

Table 2. Experience as signalman (yr)

	Mean	Median	Standard Deviation
All Signalmen	18.1	19.5	11.4
Construction	12.9	8.9	10.3
Non-Construction	20.2	24.0	11.1

Table 3. Experience with current employer (yr)

	Mean	Median	Standard Deviation
All Signalmen	16.3	14.1	11.5
Construction	12.5	8.8	11.9
Non-Construction	17.9	18.7	11.0

3.3.3 Sex and Age

Railroad signalmen are a predominantly male population. Of the 389 total usable responses, 386 (99.2 percent) were from male signalmen, and only 3 (0.8 percent) were from females. Because of the limited number of females, segregation of results by sex was not meaningful.

The average overall age for this group was 44.5 yr. While the two groups of signalmen differ substantially in their experience levels, in terms of age they are quite similar, with those working construction jobs being only 3.5 yr younger on average than their non-construction counterparts (see Table 4). This indicates that although the working groups are close to the same age, those with more experience and therefore more seniority choose to work non-construction jobs.

Table 4. Signalman age (yr)

	Mean	Median	Standard Deviation
All Signalmen	44.5	46	9.3
Construction	42	43	9.4
Non-Construction	45.5	47	9.1

Figure 3 displays the age distribution for signalmen, based on the survey results. Nearly three quarters of all signalmen are 40 yr and older.

Research has found that a higher perceived age, relative to chronological age, can be an indicator of chronic stress and poor psychological well-being (Barnes-Farrell and Petrowski, 1989,1991). Overall, the signalmen reported a lower perceived age (41.6 yr) in comparison with their average chronological age (44.5 yr). A comparison of the survey responses by age group showed the majority of those over 40 reported feeling the same or younger than their chronological age while those under 40 were less likely to report feeling younger than their chronological age (see Table 5). This is the same pattern that Barnes-Farrell and Petrowski found with the permanent day shift workers in a manufacturing plant. In contrast with the Barnes-Farrell and Petrowski research, a larger proportion of the under-40 signalmen report feeling older than their chronological age; however, additional investigation is necessary before concluding that it is due to job stress. As Barnes-Farrell and Petrowski point out, younger people tend to report feeling older to reflect perceived maturity.

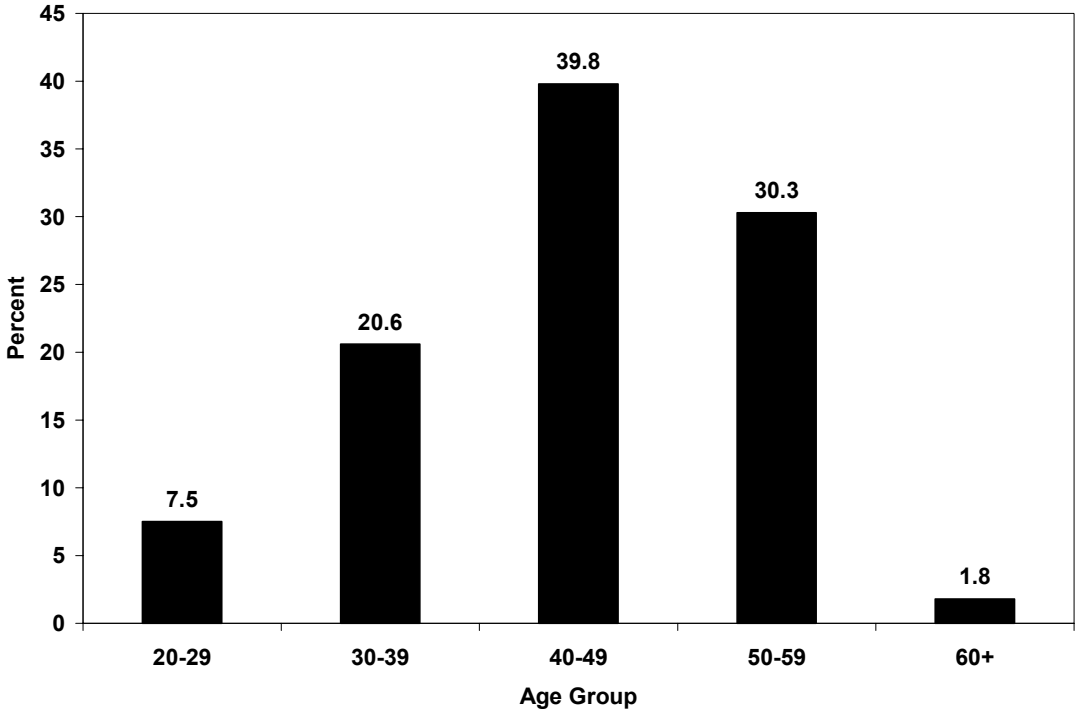

Figure 3. Distribution of signalmen by age group

Table 5. Discrepancies between chronological and perceived age by age group (percent)

Age Perception	Signalman Age (yr) 18-29	30-39	40-49	50+
Younger	28.6	41.3	50.0	50.4
Same Age	42.9	25.0	27.6	31.2
Older	28.6	30	19.2	13.6

The difference between actual age and perceived age by job type was also investigated. Although those working construction jobs reported feeling, on average, 3.7 yr younger than their actual age, and non-construction signalmen reported feeling 2.5 yr younger than their actual age, these differences were not statistically significant, $t(373) = -1.419$, $p = .157$.

3.3.4 Marital and Family Status

Most recent statistical data from the U.S. Census indicates that 58.9 percent of the U.S. male population 18 and older are married (U.S. Census Bureau, 2003). At the time of the study, 85.3 percent of participants were married, 7.7 percent were divorced, 5.7 percent single, 0.5 percent widowed, and 0.8 percent fell into the other category (these people were likely separated or living together). Since many railroaders report that their work schedule strains marital relationships, finding such a high proportion of signalmen to be married was surprising. This

data does not indicate, however, whether or not the married individuals were in an initial marriage or one subsequent to a divorce.

Participants also reported whether or not their family included young children, a factor that can lead to disrupted sleep. While a large percentage of signalmen are married, relatively few have children under the age of two (9.2 percent). A small percentage had one child under the age of two (7.7 percent), and 1.5 percent had two children under 2 yr. This finding is not surprising given the average age of a signalman.

3.3.5 Health

Participants rated their health via a Likert scale. Scale values ranged from 1–4; with 1–excellent, 2–good, 3–fair, and 4–poor. Nearly a quarter of the signalmen rated their health as excellent, and approximately 62 percent rated it as good (see Figure 4). Taken together, over 86 percent of signalmen rated themselves in good or excellent health. These ratings are reflected in the relatively small number of workdays missed due to sickness in the last 6 mo. More than 84 percent of participants had not taken a sick day off in the last 6 mo. Only 7.7 percent took 1 d off, 4.1 percent took 2 d, 2.1 percent took 3 d, and 1.5 percent took more than 3 d in the previous 6 mo (see Figure 5). The low number of workdays lost due to illness may be due in part to the fact that signalmen are not compensated for sick days.

Although statistically significant correlations existed between perceived health and alertness at work and perceived health and drained after work, these correlations were very weak, with only 6 percent of the variation in one variable being explained by the other. In both cases $r = .253$, $r^2 = .064$, $p = .000$.

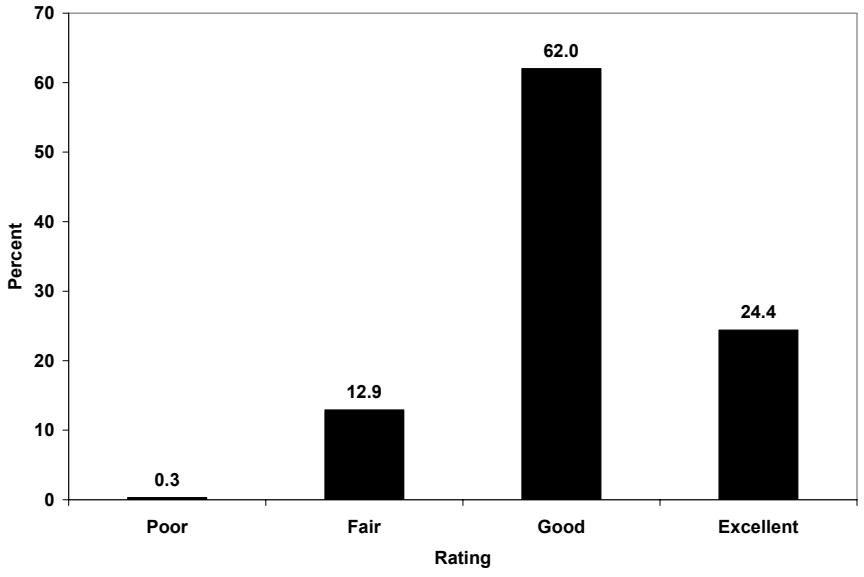

Figure 4. Self-assessment of overall health

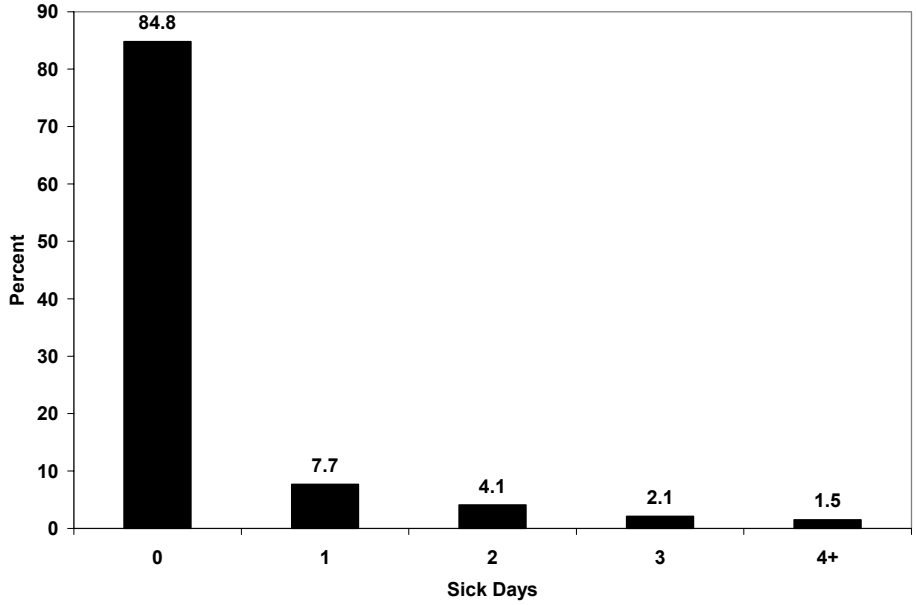

Figure 5. Workdays lost to illness in last 6 months

3.3.6 Incidence of Sleep Disorders

The Wisconsin Sleep Cohort Study, a longitudinal study of cardiopulmonary sleep disorders among middle-aged working adults, estimated that 2 percent of women and 4 percent of men have sleep apnea (Young, Palta, Dempsey, Skatrud, Weber and Badr, 1993). (The definition of sleep apnea for this study was an apnea-hypopnea score of 5 or higher and daytime hypersomnolence.) The National Sleep Foundation and the National Institutes of Health report these numbers as an estimate of the prevalence of sleep apnea. Some sleep researchers hypothesize that the prevalence of sleep apnea may in fact be higher because many cases remain undiagnosed. According to the Wisconsin study, 9 percent of women and 24 percent of men have undiagnosed sleep-disordered breathing, a condition that in some people results in excessive daytime sleepiness.

Of the 389 participants in the signalmen study, 22, or 5.7 percent, reported having a diagnosed sleep disorder. Fifteen of those people (68.2 percent) reported being treated for the sleep disorder, with seven reporting no treatment (31.8 percent). The seven individuals with a diagnosed but untreated sleep disorder account for 1.8 percent of the total group of signalmen. The background survey that solicited this information inquired about diagnosed sleep disorders, not sleep apnea specifically. It is possible that some of the people reporting a diagnosed sleep disorder have sleep-disordered breathing and not sleep apnea. (Sleep-disordered breathing does not necessarily lead to excessive daytime sleepiness and as such is a less problematic sleep disorder than sleep apnea.) For this reason, it is not possible to conclude with certainty that signalmen have a higher rate of sleep apnea than the U.S. adult male population. The fact that signalmen do report a higher rate of sleep apnea and/or sleep disorders may be due to increased awareness of the condition among signalmen. In recent years, both the railroads and BRS have conducted educational campaigns on the subject and encouraged individuals with symptoms of sleep apnea to seek medical evaluation.

3.3.7 Consumption of Caffeinated Beverages

The National Sleep Foundation (NSF) reports that 250 mg of caffeine a day–the equivalent of a soda and a couple of coffees–generally poses no harm. Almost all participants reported consuming caffeinated beverages on a daily basis (89.5 percent), and those who did averaged 3.3 beverages a day. Based on this level of caffeine consumption, railroad signalmen are within normal healthy limits, and their sleep, in general, is likely not disrupted due to caffeine unless the caffeine is consumed close to bedtime (NSF, 2002).

3.3.8 Summary of Signalmen Demographic Characteristics

At the time of the study, signalmen held primarily maintenance jobs (65 percent) and construction jobs (29 percent). The remainder worked yard maintenance. Average signalman experience was approximately 18 yr, but construction jobs had 7 yr less experience than non-construction signalmen. All but three participants were male. The majority of signalmen are middle-aged but report feeling 3 yr younger than their chronological age. Nearly all participants were married with no young children, and nearly all report being in good or excellent health with no sick days in the last 6 mo. Approximately 6 percent reported having a diagnosed sleep disorder, and almost one third of those have gone without treatment. The true number of sleep disorders may be higher, as some may have an undiagnosed sleep disorder. Participants averaged 3.3 caffeinated beverages daily, which pose no harm or health risks.

3.4 Job Characteristics

This section explores several aspects of the signalman's job including work schedule, commute time, number of hours worked, and sources of stress. The section also discusses the relationship between alertness and schedule characteristics.

3.4.1 Work Schedule

Weekly work schedules fell into three basic categories: 4-d week, 5-d week, and 8-on 6-off (8 straight days of work followed by 6 straight days off). Half of those holding construction jobs worked a 4-d week, with the other half divided between a 5-d week and an 8-on 6-off schedule. Nearly all of the non-construction signalmen worked a 5-d week, with only a small number working a 4-d week (see Table 6).

Table 6. Work schedule by job type

	Job Type	
Work Schedule	**Construction**	**Non-Construction**
4-d week	50.5 %	3.2 %
5-d week	22.5 %	95.7 %
8-on 6-off	26.1 %	0 %
Other	0.9 %	0 %
Not reported	0 %	1.1 %

Signalmen provided information about their nominal workday (as defined by their labor agreement), in terms of start and end times of the workday, in the background survey. They reported their actual start and end times in the daily logs. The computation for actual work includes only those individuals who reported a full 2 weeks of data, although these individuals may not have worked a full 2 weeks. Table 7 presents both the mean and median values for nominal and actual workdays by job type. Median values provide the most meaningful comparison for this information. The median start time for both construction and non-construction jobs is 7 a.m. Because many construction signalmen work four 10-h days, their day ends at 5 p.m. while the non-construction signalman typically ends the regular workday at 3:30 p.m. Both groups have a median lunch break of 30 min. The mean and median values for start time, end time, and lunch break for construction people are nearly identical, indicating that these values are not skewed. In contrast, non-construction signalmen's mean start time is 31 min later than the median, indicating that some workers have much later start times, making the mean time later. Of the 278 non-construction signalmen, 15 worked either second or third shift, and 38 started work at 7:30 a.m.

Table 7. Workday by job type

	Construction		Non-Construction	
	Mean	**Median**	**Mean**	**Median**
Start time (nominal)	6:59 a.m.	7 a.m.	7:31 a.m.	7 a.m.
Start time (actual)	7:13 a.m.	7 a.m.	7:38 a.m.	7 a.m.
End time (nominal)	4:56 p.m.	5 p.m.	3:36 p.m.	3:30 p.m.
End time (actual)	4:39 p.m.	5 p.m.	3:51 p.m.	4 p.m.
Length of meal break (nominal)	35 min	30 min	37 min	30 min

Start time variability can lead to fatigue if it disrupts the worker's normal sleep pattern. Backward rotation of the start time (i.e., when one starts work earlier than the prior day) can be especially problematic. Examination of start time variation provided a means to assess work schedule variability. This analysis defined variation in start time as a change in start time of more than 1 h from the previous day. In the 2-week timeframe of the study, 10 percent of construction signalmen and 37 percent of the non-construction signalmen experienced start time variation at least once. This relationship between start time variability and job type is statistically significant, X^2 (4, n = 389) = 26.93, $p < .05$. That is, start time variability is not independent of job type. Further, on those days with a start time variance from the previous day, alertness levels were significantly lower compared to days on which start time was not varied from the previous day, $t(5376) = -6.579$, $p < .05$. The higher level of variability in non-construction signalmen's schedules was likely due to their need to respond to emergencies. Table 8 presents the frequency of start time variability by type of job.

In the background survey, both job types reported that the longest time they work without a break is approximately 4 h (see Table 9). This result is consistent with the contractual provision for a meal break after 4 h on the job.

Table 8. Start time variability by job type

Number of Start Time Variations (in 2-Week Period)	Job Type	
	Construction	Non-Construction
0	89.9 %	62.9 %
1	4.6 %	12.9 %
2	1.8 %	15.7 %
3	2.8 %	5.0 %
4+	0.9 %	3.6 %

Table 9. Longest time working without a break by job type (h:min)

Job	Mean	Median
Construction	4:10	4:00
Non-Construction	4:01	4:00

3.4.2 Number of Hours Worked

The study collected data on a typical work week, nominal work week and actual hours worked. On average, signalmen reported (in the background survey) a typical work week to be 45:28. Construction signalmen reported working 43:34 and non-construction 46:13. In a 2-week period, this equates to 87:08 for construction signalmen and 92:26 for non-construction (see Table 10). Nominal work was calculated based on the employee's job characteristics as reported in the background survey. Actual work for 2 weeks was computed from the daily logs.

For both job types, the average actual work for the 2-week period was less than typical work but was greater than nominal work.[3] In other words, participants worked less than they said they typically do but more than their normal, or nominal, schedules dictate. The difference between nominal and actual work schedules is likely due to any overtime extension of the nominal daily work period, or a callback to respond to an emergency at night or on a planned day off.

Although the nominal schedules for both groups of signalman require 80 h of work in 2 weeks, the typical and actual work hours for the non-construction group were larger than that of the construction group. During the survey period, half of the non-construction signalmen worked 84:30 or more and one quarter worked 92:50 or more (see 75th percentile in Table 10). This is equivalent to at least one and a half additional 8-h d in a 2-week period. This result is likely due to the emergency calls that non-construction signalmen must handle.

[3] Daily work period was defined as the elapsed time between start and end times minus the lunch break. Nominal work for the 2-week period was the daily work period times the number days scheduled to work in 2 weeks.

Table 10. Typical, nominal, and actual work for 2-week period (h:min)

	Construction					Non-construction				
	Mean	Median	Std. Dev.	25th %	75th %	Mean	Median	Std. Dev.	25th %	75th %
Typical Work	87:08	80:00	15:42	80:00	88:00	92:26	90:00	12:14	80:00	100:00
Nominal Work	80:37	80:00	8:00	77:20	80:00	79:18	80:00	2:31	80:00	80:00
Actual Work	83:16	80:00	16:07	73:58	88:19	87:32	85:25	14:01	79:07	92:50

The information provided by the survey respondents indicates that the survey period was one of lighter workload. The typical work, as reported on the background survey, and the actual work, as recorded in the daily logs, support this observation. Comparison with ASTE data for signalmen provided another means to conclude that the survey period was one of lighter than normal workload. ASTE is the average number of hours that a signalman was compensated for in a given year. For 2002, the ASTE was 2763 h (personal communication with BRS). To compare this number with the survey data, several adjustments to both ASTE and the survey data were necessary to make the two figures comparable. Appendix B describes these adjustments. After the adjustments, a difference of 5.3 h per week existed between the ASTE and the survey results. Based on this comparison, during the period of this survey, signalmen worked on average 5.3 h per week less than the yearly workload average.

3.4.3 Unscheduled Work Periods

This study defined unscheduled work periods as any work period that was not in the employee's nominal work schedule and that occurred after the employee began the trip home at the end of the workday or on a planned day off. Overtime that was an extension of the nominal work schedule was not an unscheduled work period. Callbacks, a subset of unscheduled work periods, are unscheduled work periods that occur on a regular workday. Because construction signalmen are rarely called out to work beyond regular work hours, all calculations for unscheduled work periods and callbacks included only non-construction signalmen.

Nearly two-thirds of signalmen (63.9 percent) had at least one unscheduled work period in the 2-week period of the study. A signalman was twice as likely to get called in for an unscheduled work period on a planned day off as on a regular workday (.18 and .09 percent, respectively). Based on the study period, signalmen averaged 1.9 unscheduled work periods per worker per 2-week period. Overall, the probability of getting called in to work an unscheduled work period on any given day was .12. If a signalman worked an unscheduled work period, the probability of that person being called back a second time was .14 and a third time, .04.

The time between the end of shift (on a workday) and the time called back to work (for an unscheduled work period) averaged 5:12. First and second callbacks (after regular work) lasted just over 2:20. The Hours of Service Law effectively limits the length of the callback work periods. For example, if a signalman works 10 h in a day, then s/he can only work another 2 h and then must have 8 h off. Only three instances of a third callback in one night occurred.

3.4.4 Commute Time

Construction signalmen can sometimes work considerable distances from their residence. In order to eliminate long drives home each night, contractual provisions often require the railroad to provide lodging or some form of stipend to cover the cost of overnight stays during the work week. Signalmen may choose to sleep at this lodging/rally point throughout the work week or return home each night after work and reconvene at the rally point each morning. Often times, an employee will leave home on a Sunday evening and travel to this lodging/rally point. Because most work cycles tended to start on a Monday, daily entries into the diary also began on Monday and therefore did not tend to capture this Sunday commute. Review of the diaries indicates, however, that some individuals may have included the trip home at the end of the work cycle. Some individuals correctly logged their commute all the way home at the end of the work week and not the trip back to the rally point. This problem in the way the data was collected caused the survey results to underestimate the commute time for construction signalmen.

For all signalmen together, commute time to work averaged 33 min, while time to commute home averaged 38 min. Breaking commute time by job type reveals slightly longer commutes home for construction jobs than non-construction jobs (42 min and 36 min, respectively) while commute time to work was similar. Again, this longer commute home may result from construction signalmen who reported their commute all the way home at the end of the work week and not just the commute back to the rally point.

Commute time with respect to job schedule indicates that those working 8-on 6-off schedules have shorter commute times than those with other schedules. These shorter commute times are to be expected since many of those working 8-on 6-off are returning to nearby lodging each night, until the end of the work cycle when they (typically) make the long trip home (see Figure 6).

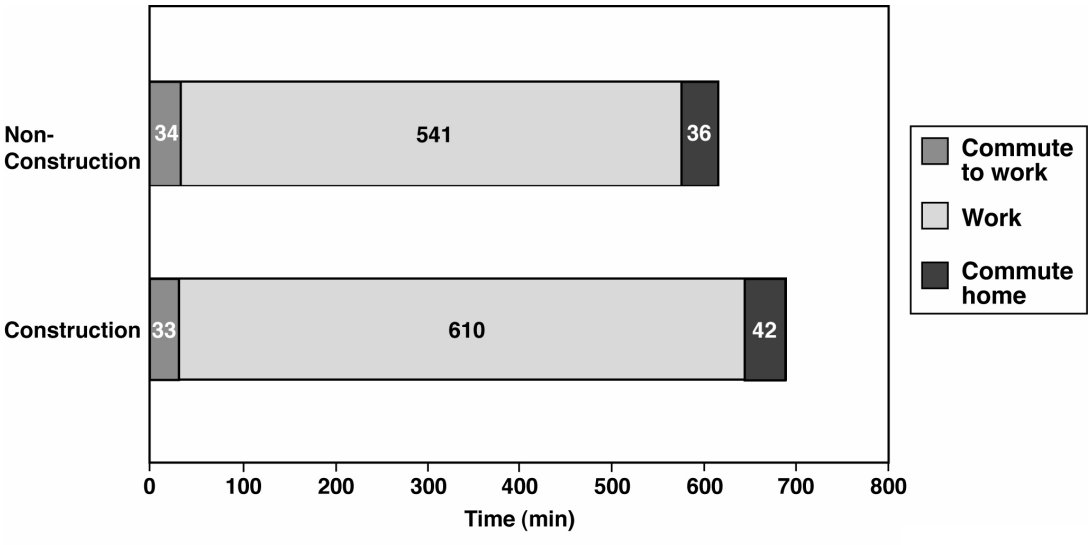

Figure 6. Commute time and workday by job type

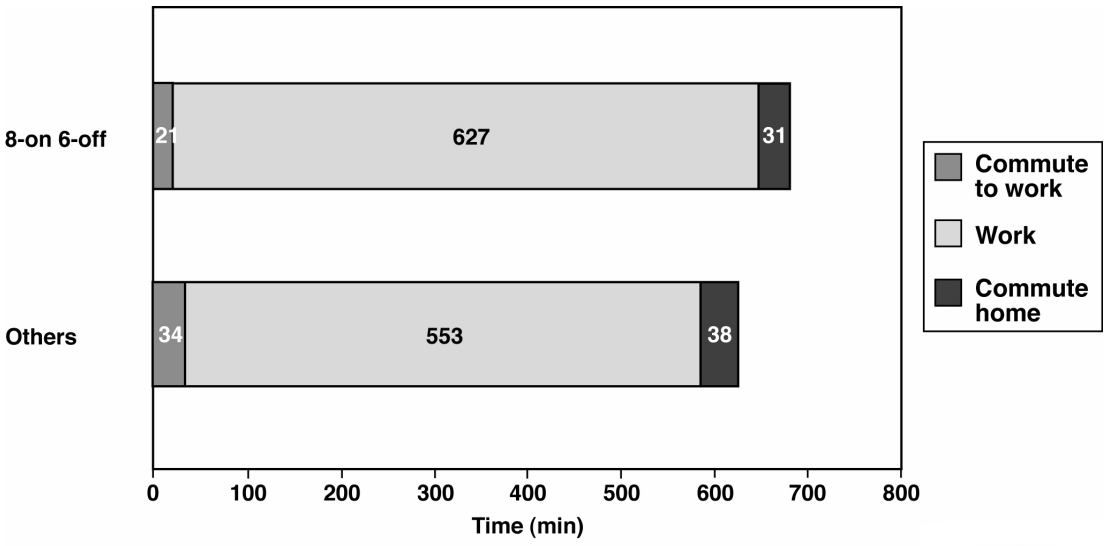

Figure 7. Commute time and workday by job schedule

3.4.5 Work Schedules and Alertness

Through questions on the background survey, signalmen rated their overall alertness at work and after work. Construction signalmen generally reported being alert at work more often and drained after work less often than non-construction signalmen (see Tables 11 and 12). Neither of these differences, however, is statistically significant. For alert at work ratings between construction and non-construction signalmen, $X^2(3, n = 384) = 2.51$, $p = .47$. Differences between the groups for alertness (drained) after work approached significance, $X^2(3, n = 386) = 7.66$, $p = .054$.

Table 11. Alertness at work by job type

Alert at Work?	Construction	Non-Construction
Always	10.9 %	8.8 %
Frequently	59.1 %	55.8 %
Occasionally	30.0 %	33.9 %
Never	--	1.5 %

Table 12. Drained after work by job type

Drained After Work?	Construction	Non-Construction
Always	0.9 %	5.4 %
Frequently	34.5 %	29.0 %
Occasionally	60.9 %	64.5 %
Never	3.6 %	1.1 %

Data from participants' daily logs did reveal a statistically significant difference between the two groups in alertness assessments. The daily log data indicate that construction signalmen had higher alertness ratings than non-construction signalmen throughout the day. A series of *t*-tests, shown in Table 13, validates this difference. Generally, peak alertness for both groups was just after arriving at work (based on work schedule data, this is around 7 a.m.), after which alertness levels declined throughout the rest of the day (see Table 13).

Table 13. Alertness throughout the day by job type

	Job Type		
Time of Rating	**Construction**	**Non-Construction**	**Significance Test**
Upon awakening	3.6	3.4	$t\,(3608) = 4.38, p < .05$
After commute to work	3.8	3.7	$t\,(3563) = 3.89, p < .05$
After lunch	3.8	3.6	$t\,(3501) = 6.10, p < .05$
After arriving home	3.3	3.1	$t\,(3135) = 3.47, p < .05$
At bedtime	2.7	2.4	$t\,(2584) = 6.93, p < .05$

The study explored the relationship between several aspects of the signalmen's work schedules and alertness. One issue was the relationship between consecutive workday and morning alertness. No significant correlation existed between consecutive workday and mean morning alertness rating, $r = .010$, $r^2 = .0001$, $p = .540$, and no significant differences existed in morning alertness by consecutive workday, $F(4,3605) = .299$, $p = .879$.

Unscheduled work periods appear to affect morning alertness ratings (see Table 14). Alertness levels the morning following a callback were significantly lower than on mornings not following a callback, $t\,(3433) = 3.440$, $p < .05$. However, the effect size for this relationship was .23. (The *t*-test is an indication of the strength of the relationship, while the effect size is a measure of the degree to which a relationship exists between callbacks and morning alertness.) According to Cohen (1988), this is a small effect size. Cohen (1988, p. 23) also suggests that the effect size (ES) can be converted to *r* and r^2 using the following relationship:

$$r = \frac{ES}{\sqrt{ES^2 + (1/pq)}}$$

where p = proportion with callbacks and q = proportion without callbacks. Using this formula, $r = .059$ and $r^2 = .003$, which means that callbacks explain only .3 percent of the variance in morning alertness. A X^2 test investigating callbacks and morning alertness supports the hypothesis that alertness ratings are not independent of callbacks, i.e., there is a relationship between callbacks and morning alertness, $X^2(4, n = 3435) = 22.81$, $p < .05$.

Table 14. Alertness and unscheduled work periods

	Morning Alertness Rating	
	Mean	**Median**
Following callback	3.3	3.0
No callback	3.6	4.0

This study also examined the relationship between commute time, number of hours worked and time without a break, and alertness. Commute time did not affect alertness levels. Although statistically significant relationships existed between commute times (to and from work) and alertness, the correlations were very weak. For commute to work and alertness level upon arriving at work, $r = -.048$, $r^2 = .002$, $p < .05$, and for commute home and alertness level upon arriving home, $r = -.096$, $r^2 = .009$, $p < .05$.

The number of hours worked in a day (not including unscheduled work periods after arriving home) did not affect alertness upon arriving at home from work. Although the correlation between the two variables was statistically significant, the strength of the relationship was very weak, $r = -.126$, $r^2 = .016$, $p < .05$.

A statistically significant relationship existed between time without break and alertness upon arriving home, but once again the correlation was very weak, $r = -.179$, $r^2 = .032$, $p < .05$.

3.4.6 Sources of Stress

In the background survey, participants rated job-related sources of stress. They rated stress via a Likert scale, with values from 1–4, with 1–no stress, 2–a little stress, 3–stressful, and 4–very stressful. Overall, management policies, scanty rules, inadequate staffing, job pressure, and emergencies were, respectively, the top five most stressful issues (see Figure 8 and Table 15). The sources and levels of stress differed by job type. In six categories, non-construction signalmen reported statistically significant higher levels of stress than construction signalmen. This may be due, at least in part, to the variable job schedule and frequent unscheduled work periods of non-construction signalmen. Only in the case of travel to work, did construction signalmen report statistically significant higher levels of stress than non-construction signalmen. This is not unexpected since signalmen working construction jobs must often travel great distances on a day off to reach a lodging facility in preparation for the work cycle. The five categories which resulted in the greatest difference in ratings between the two job types were the following: on-call schedule, emergencies, inadequate staffing, work rules, and sleep loss. Emergencies and on-call schedules are not typical for construction signalmen and do not lead to sleep loss. As such, they are not as stressful to those working construction jobs as they are to those working non-construction jobs.

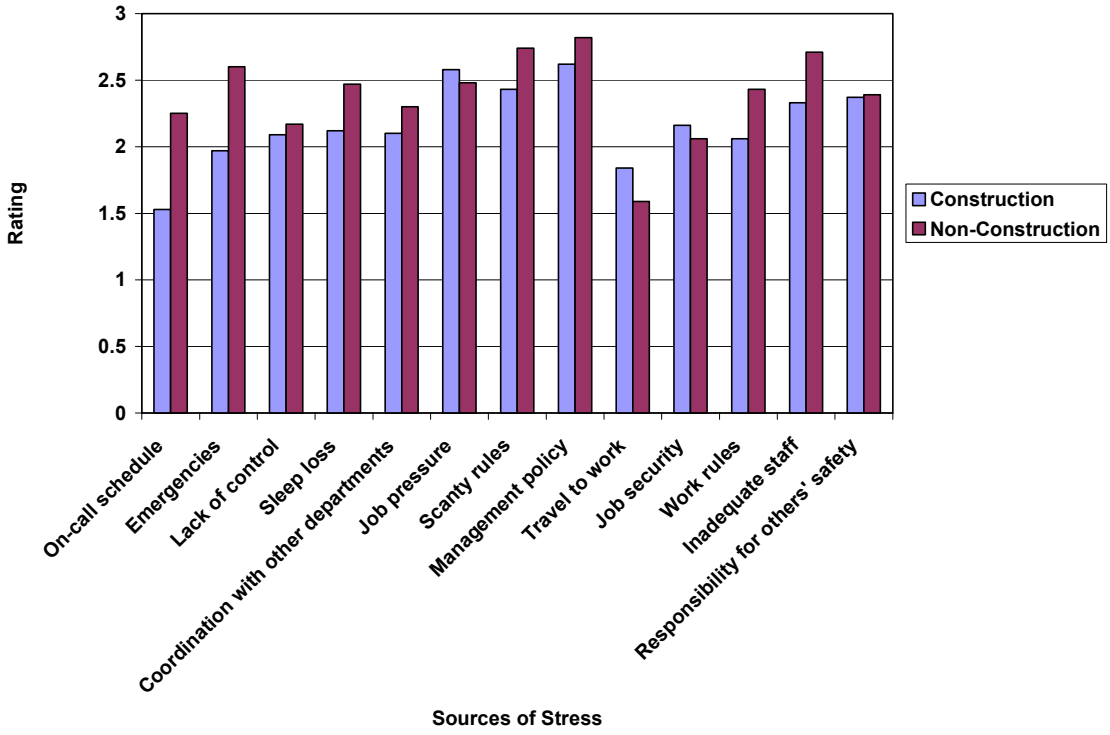

Figure 8. Sources and levels of stress

3.4.7 Job Characteristics Summary

The work schedules of construction and non-construction signalmen differ in several respects. While both types of jobs nominally work 80 h in a 2-week period, nearly all non-construction jobs have a 5-d work week, but less than a quarter of the construction jobs have this schedule. Half of all construction jobs work a 4-d week, and a quarter work 8-on 6-off. During the 2-week survey period, non-construction signalmen worked 87.5 h, and the construction signalmen worked 83.25. This difference was likely due to emergency calls and other unscheduled work that non-construction signalmen must handle. Over a third of non-construction signalmen experienced start time variability at least once during the survey period, most likely as a result of an emergency call or unscheduled work.

The non-construction signalmen averaged 1.9 unscheduled work periods in 2 weeks. On any given day, the probability of an unscheduled work period was .12. Once called for an unscheduled work period, a signalman had a 14 percent chance of being called back a second time. An unscheduled work period on a work night affected morning alertness; however, the effect size was somewhat small.

Table 15. Stress ratings by job type

Sources of Stress	Construction	Non-Construction	Significance Test
On-call schedule	1.53	2.24	$t(375) = -7.04$, $p < .05$
Emergencies	1.97	2.61	$t(376) = -5.90$, $p < .05$
Lack of control	2.09	2.17	$t(378) = -.74$, $p = .459$*
Sleep loss	2.12	2.47	$t(380) = -3.44$, $p < .05$
Coordination with other departments	2.10	2.31	$t(376) = -1.93$, $p = .054$*
Job pressure	2.58	2.47	$t(377) = 1.00$, $p = .317$*
Scanty rules	2.43	2.73	$t(377) = -2.81$, $p < .05$
Management policies	2.62	2.82	$t(379) = -1.80$, $p = .073$*
Travel to work	1.84	1.59	$t(378) = 2.56$, $p < .05$
Job security	2.16	2.06	$t(379) = .86$, $p = .393$*
Work rules	2.06	2.42	$t(379) = -3.28$, $p < .05$
Inadequate staff	2.33	2.71	$t(378) = -3.07$, $p < .05$
Responsibility for others' safety	2.37	2.40	$t(380) = -.27$, $p = .791$*

*Not significant at $p < .05$

Sources of work-related stress were different for the two groups of signalmen. Only in the case of travel to work did construction signalmen report a statistically different and higher level of stress than their non-construction counterparts. On-call schedule, emergencies, and sleep loss were all statistically different and greater sources of stress to non-construction signalmen.

3.5 Sleep Characteristics

The study examined nighttime sleep, as well as supplementary naps. The duration and quality of sleep were considered for both workdays and planned days off.

Analysis of the sleep and nap data required a way to distinguish between naps and split nighttime sleep. For workday entries, if the nap began after the person went to sleep, but before s/he began the commute to work, then it was considered split nighttime sleep and added to nighttime sleep duration. This adjustment was not made for those who worked the night shift (defined as a start time between 6 p.m. and 1 a.m.) since these individuals could potentially have a legitimate nap after bedtime but before the commute to work. For nap entries on planned days off, if the nap began between 12 a.m. and 7 a.m., then the nap duration was added to nighttime sleep duration. The nap analysis did not include naps that were considered split nighttime sleep and, as a result, were combined with nighttime sleep duration.

3.5.1 Nighttime Sleep

Table 16 presents nighttime sleep duration for the two groups of signalmen and U.S. adults. The NSF *2002 "Sleep in America" Poll* is the source of the data for U.S. adult norms. In terms of mean nighttime sleep, signalmen are averaging less sleep on regular workdays than U.S. adults, but on planned days off they are averaging more. In terms of median nighttime sleep, however, signalmen get less regardless of type of day. A statistically significant difference existed between average signalmen's sleep and that of U.S. adults (see Table 17).

Table 16. Nighttime sleep duration versus U.S. adult norms by type of day (h:min)

Day	Group	Mean	Median	Std. Dev.	25%	75%
Regular Workday	Construction	6:43	6:41	0:47	6:15	7:12
	Non-Construction	6:45	6:47	0:46	6:21	7:13
	U.S. Adults	6:54	7:00	--	--	--
Planned Day Off	Construction	7:52	7:56	1:10	7:10	8:36
	Non-Construction	7:42	7:40	1:07	7:02	8:21
	U.S. Adults	7:30	8:00	--	--	--

Table 17. Nighttime sleep duration (mean)–tests for significance

Type of Day	Comparison	Significance Test
Regular Workdays	Construction versus U.S.	$t(108) = -2.44$, $p < .05$
	Non-Construction versus U.S.	$t(278) = -4.0$, $p < .05$
	Construction versus Non-Construction	$t(386) = -.237$, $p = .813$*
Planned Days Off	Construction versus U.S.	$t(106) = 3.24$, $p < .05$
	Non-Construction versus U.S.	$t(271) = 4.43$, $p < .05$
	Construction versus Non-Construction	$t(377) = 1.341$, $p = .181$*

*Not significant at $p < .05$

No significant differences existed between the nighttime sleep durations of construction and non-construction signalmen for both workdays and planned days off. Both construction and non-construction signalmen, however, averaged significantly longer sleep durations on planned days off compared to regular workdays, $t(108) = 15.33$, $p < .05$, and $t(278) = 20.73$, $p < .05$, respectively.

Figure 9 presents a frequency distribution of nighttime sleep on workdays for all signalmen in comparison with the data from the NSF survey mentioned above. Almost two thirds of

signalmen are getting less than 7 h sleep on work nights in contrast with 39 percent of U.S. adults. The proportion of signalmen getting less than 6 h of sleep is similar to that for U.S adults. Seven signalmen (1.8 percent) averaged less than 5 h sleep on work nights. Four of these individuals work a night shift and change their sleep patterns on the weekends. A fifth changed from a day to a night job during the study and experienced difficulty readjusting his sleep pattern. All seven experienced difficult life events, as indicated in the background survey, within the 6 mo before the survey. These life events likely contribute to the reduced nighttime sleep. The NSF poll did not report the percentage of U.S. adults getting less than 5 h sleep on weeknights so comparison with U.S. norms was not possible for this group.

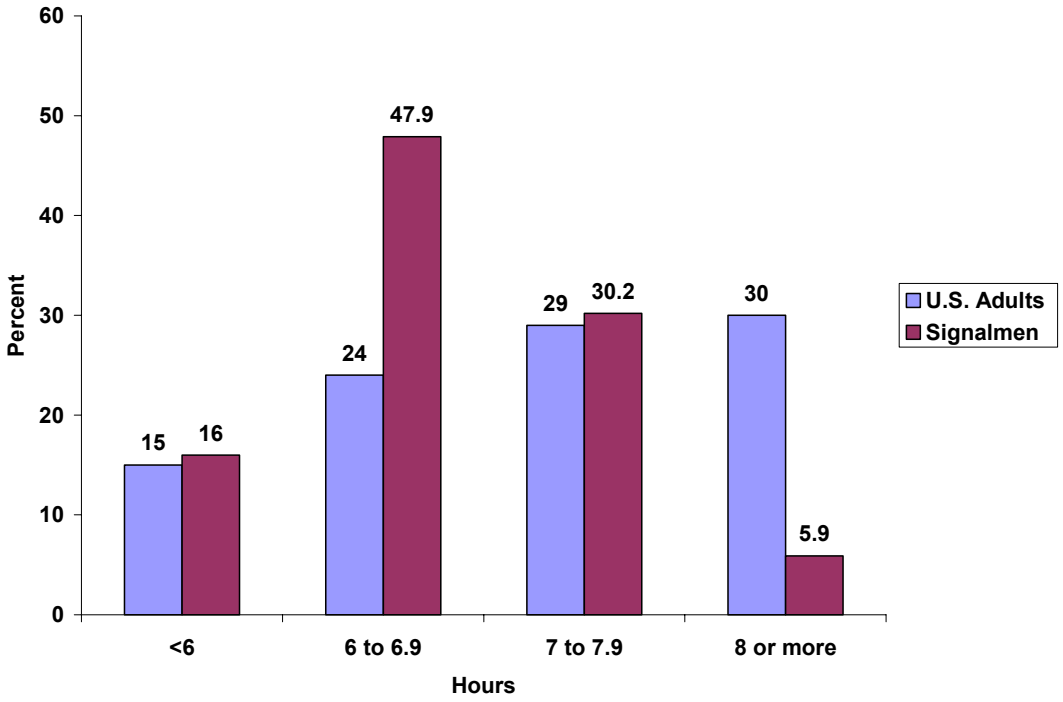

Figure 9. Duration of nighttime sleep on workdays for signalmen versus U.S. adults

Research has shown that performance declines even with mild sleep restriction. Belenky et al. (2003) have shown that performance declines initially with mild to moderate sleep restriction of 7 and 5 h, and after a few days stabilizes at a less than fully rested level. Van Dongen, Maislin, Mullington, and Dinges (2003, p. 117) concluded that,

> Since chronic restriction of sleep to 6 h or less per night produced cognitive performance deficits equivalent to up to 2 nights of total sleep deprivation, it appears that even relatively moderate sleep restriction can seriously impair waking neurobehavioral functions in healthy adults. Alertness ratings suggest that subjects were largely unaware of these increasing cognitive deficits, which may explain why the impact of chronic sleep restriction on waking cognitive functions is often assumed to be benign.

Based on the survey results, the 16 percent of signalmen getting less than 6 h of nighttime sleep on workdays may be performing significantly below that of a well-rested signalman. More disconcerting, based on the Van Dongen study, is that these individuals are probably unaware of the extent of their performance degradation.

The effect of sleep location on nighttime sleep duration was investigated for construction signalmen. Because construction signalmen may work significant distances from their primary residence, they may often sleep away from their home, in a hotel or other arrangement, closer to the worksite. This analysis examined nighttime sleep on workdays only, since nighttime sleep is influenced by type of day. The survey data indicate that sleep location influences nighttime sleep duration. Signalmen averaged 6:31 of nighttime sleep when at home and 6:50 when away from home. This difference was statistically significant, t (908) = -4.11, $p < .05$ and may be due to the lack of personal and family distractions when away from home.

Analysis of the survey data also investigated the relationship between job schedule and nighttime sleep duration. All job schedules averaged similar amounts of nighttime sleep on workdays; 4-d weeks–6:43; 5-d weeks–6:45; and 8-on 6-off–6:40. These slight differences were not statistically significant, $F(2,381) = .157$, $p > .05$.

As might be expected, a positive correlation existed between nighttime sleep duration and morning alertness ratings, $r = .317$, $r^2 = .100$, $p < .05$. Those getting more sleep at night tended to feel more alert in the morning, and those getting less sleep at night tended to feel less alert. The r^2 value indicates that nighttime sleep accounts for 10 percent of the variance in morning alertness.

Total sleep was the combined sleep from nighttime sleep and naps. Because signalmen in general tend not to nap (see Section 3.5.3 for further information on naps), total sleep was not a great deal more than nighttime sleep (see Table 18).

Table 18. Total sleep by type of day and job type (h:min)

Day	Job Type	Mean	Median
Regular Workday	Construction	6:47	6:46
	Non-Construction	6:51	6:51
Planned Day Off	Construction	7:58	8:01
	Non-Construction	7:51	7:51

3.5.2 Sleep Ratings

Signalmen recorded subjective ratings for sleep on both workdays and planned days off. Participants rated their ease of falling asleep, ease of arising, length of sleep, quality of sleep, and alertness upon arising. The ratings shown in Table 19 used a Likert scale ranging from 1-5, with 1 being the lowest or worst rating, while 5 indicated the highest or best. For virtually every category, construction signalmen recorded higher/better sleep scores than non-construction signalmen, and in all cases both groups reported higher/better sleep ratings on planned days off than on regular workdays. For each type of job, all sleep ratings were significantly different by type of day.

Table 19. Sleep ratings by job type and type of day

	Construction			Non-Construction		
	Regular Workday	Planned Day Off	Significance Test	Regular Workday	Planned Day Off	Significance Test
Ease of falling asleep	3.9	4.1	$t(1510) = 4.748$, $p < .05$	3.9	4.1	$t(3862) = 6.769$, $p < .05$
Ease of arising	3.4	3.6	$t(1509) = 5.152$, $p < .05$	3.2	3.5	$t(3860) = 8.442$, $p < .05$
Length of sleep	3.4	3.8	$t(1510) = 7.992$, $p < .05$	3.3	3.7	$t(3863) = 11.574$, $p < .05$
Quality of sleep	3.5	3.9	$t(1509) = 7.197$, $p < .05$	3.4	3.8	$t(3866) = 10.488$, $p < .05$
Alertness upon arising	3.6	3.9	$t(1509) = 6.407$, $p < .05$	3.4	3.7	$t(3865) = 8.420$, $p < .05$

As mentioned previously, construction signalmen may work significant distances from their primary residence and may often sleep away from their home, in a hotel or other arrangement, closer to the worksite. Data from construction signalmen indicated that (on workdays) their sleep ratings were higher at home than away from home (see Table 20); however, only the differences in ratings for ease of falling asleep and quality of sleep were statistically significant. Interestingly, although construction signalmen sleep longer when away from home, they rate their sleep at home of higher quality and report falling asleep more easily at home.

Table 20. Sleep ratings by location (construction signalmen on workdays only)

	Home	Away from Home	Significance Test
Ease of falling asleep	3.93	3.79	$t(920) = 2.0$, $p < .05$
Ease of arising	3.39	3.31	$t(919) = 1.01$, $p = .311$*
Length of sleep	3.46	3.37	$t(920) = 1.41$, $p = .158$*
Quality of sleep	3.72	3.40	$t(920) = 4.64$, $p < .05$
Alertness upon arising	3.64	3.55	$t(920) = 1.46$, $p = .146$*

* Not significant $p < .05$

No significant relationship existed between age and sleep quality ratings, $r = .003$, $r^2 = .000009$, $p = .959$. This was somewhat surprising because the durations of Stage 1 and Stage 2 sleep increase with age while rapid eye movement (REM) sleep and slow wave sleep decrease (Ohayon, Carskadon, Guilleminault and Vitiello, 2004).

3.5.3 Naps

Data from subjects' daily logs indicate that signalmen in general do not nap a great deal. Participants averaged 1.6 naps in 2 weeks. More than half of the signalmen took no naps during

the 2 weeks of the study, and 16 percent took only 1 nap over the 2-week period. The average nap duration was 1:04, and the median was 0:58.

The non-construction group napped more frequently than the construction group. Non-construction signalmen averaged 1.8 naps in a 2-week period, while construction signalmen averaged 1.1 naps, a statistically significant difference, $t(387) = -2.338$, $p < .05$.

Type of day did not influence the number of naps taken, $X^2(2, n = 5446) = 1.64$, $p = .441$. On both regular workdays and planned days off, no naps were taken approximately 90 percent of the time, one nap was taken approximately 10 percent of the time, and two naps were very rare (see Table 21).

Table 21. Number of naps by type of day

	Number of Naps	Percent
Regular Workdays	0	88.9
	1	10.6
	2	0.5
Planned Days Off	0	90
	1	9.6
	2	0.4

Although type of day did not affect the frequency of naps, signalmen tended to nap for longer periods on planned days off than on workdays, $t(583) = 4.233$, $p < .05$. On workdays their naps averaged 0:53 and on days off 1:12. As with nighttime sleep duration, signalmen may be making up for a weeknight sleep deficit with longer naps on their days off.

Nap frequency varied by work schedule. Those working 4-d weeks averaged only 0.7 naps in 2 weeks, those with 8-on 6-off averaged 1.6 naps in 2 weeks, and those working 5-d weeks averaged 1.8 naps over the 2-week period. A one-way ANOVA revealed statistical significance between groups, $F(2,382) = 5.03$, $p < .05$. Scheffe's post hoc analysis found a statistical difference between the number of naps taken by those working 4-d weeks and those working 5-d weeks only.

Naps occurred at various times throughout the day. Over 29 percent of the first naps began between 4–6 p.m., just after work in most cases. Other popular (first) nap start times were 2–4 p.m. (18.6 percent), 12–2 p.m. (16.8 percent), and 6–8 p.m. (16.2 percent). Figure 10 contains the distribution of nap start times. Two individuals who worked night shift and napped during their break at work were responsible for all of the early morning naps.

Sixteen signalmen reported more than one nap on a given day (see Figure 11). This group reported 24 occurrences of a second nap (of the day) during the 2 weeks of the survey. Over 37 percent of participants opting for a second nap (for the day) began napping between 4–6 p.m. The next most frequent start time for a second nap was between 12–2 p.m. (16.7 percent).

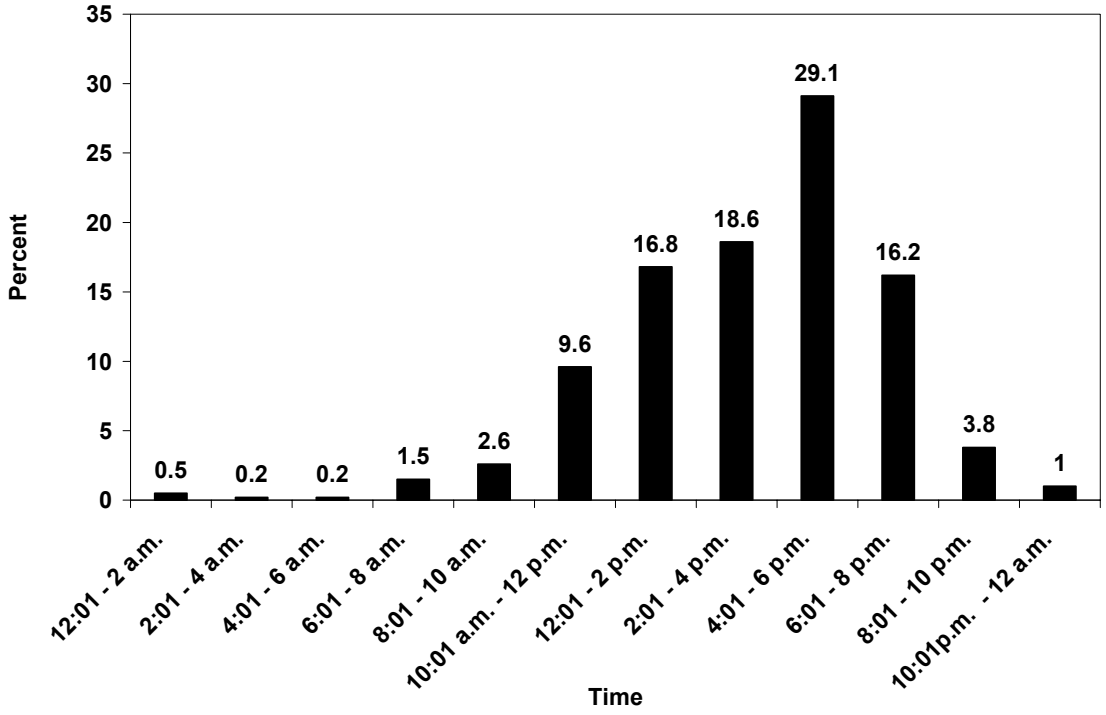

Figure 10. Distribution of nap #1 start time

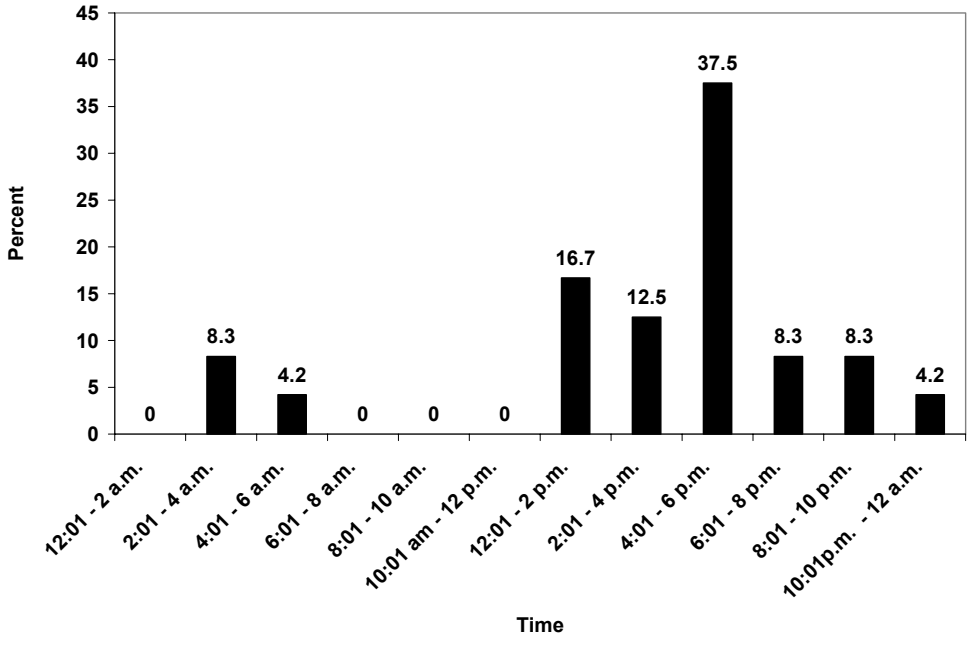

Figure 11. Distribution of nap #2 start time

3.5.4 Sleep Latency

Sleep latency is the time from lights out to onset of sleep. Sleep latency increases modestly with age. Based on a meta-analysis of sleep parameters (Ohayon et al., 2004), sleep latency, as measured in a sleep laboratory, for a 45-yr old is approximately 17 min. Mean survey results (24 min) differ from this value. Several factors explain the difference between the adult norm and the survey results. First, the survey mean is based on self-report estimates and not values determined in a sleep laboratory. Second, the diary asked for the time you went to bed not the time you turned out the lights. Some respondents commented that they watched TV or read in bed before they fell asleep. For these reasons it is not possible to conclude that sleep latency for signalmen differs from adult norms.

On both regular workdays and planned days off, non-construction signalmen are quicker to fall asleep than construction signalmen (see Table 22). This may be because non-construction signalmen report feeling less alert throughout the day. Only on planned days off was this difference significant, $t(377) = 2.64$, $p < .05$. Both groups of signalmen fell asleep more quickly on planned days off than regular workdays, although only for non-construction signalmen was this difference statistically significant, $t(271) = -5.06$, $p < .05$.

Table 22. Sleep latency by type of day (min)

	Planned Day Off		Regular Workday	
	Construction	Non-Construction	Construction	Non-Construction
Mean	24	20	26	24
Median	22	18	23	21
Standard Deviation	16	13	15	15

3.5.5 Sleep Disorders–Alertness and Sleep Ratings

There were 22 signalmen (5.7 percent) of 389 total survey respondents who reported having a diagnosed sleep disorder. Fifteen of those individuals (68 percent) reported receiving treatment for their disorder. Seven of those with a diagnosed sleep disorder (32 percent) reported that their problem was untreated.

Sleep ratings and alertness levels were compared across three groups: (1) the untreated sleep disorder group (n = 7), (2) the treated sleep disorder group (n = 15), and (3) those with no diagnosed sleep disorder or the normal group (n = 367). For every sleep rating category other than nighttime sleep duration, those with untreated sleep disorders reported poorer sleep ratings than the other two groups (see Table 23). Differences in ease of arising were not statistically significant. Interestingly, those with treated sleep disorders reported equal or better sleep ratings than the normal group, although these differences were not statistically significant. Table 24 contains test results for significance.

Similar to their sleep ratings, those with untreated sleep disorders also reported being less alert (see Table 25). At every point throughout the day that alertness was rated, those with untreated

sleep disorders had lower alertness scores than the other two groups. Again similar to the sleep ratings, those with treated sleep disorders generally had equal or higher alertness ratings than the normal group, although these differences were not statistically significant (see Table 26).

Table 23. Sleep ratings and duration by sleep disorder status

	Untreated Sleep Disorder	Treated Sleep Disorder	Normal
Ease of falling asleep	3.3	4.0	3.9
Ease of arising	2.9	3.5	3.3
Length of sleep	2.7	3.5	3.5
Quality of sleep	2.8	3.6	3.6
Nighttime sleep duration	7:10	6:59	7:05
"How feel" in morning (alertness)	2.8	3.6	3.6

Table 24. One way ANOVA and post hoc (Sheffe's) comparisons for sleep ratings by sleep disorder status

	ANOVA	Untreated versus Treated	Untreated versus Normal	Treated versus Normal
Ease of falling asleep	$F(2,386) = 3\ .99, p < .05$	$p < .05$	$p < .05$	$p = 0.962$*
Ease of arising	$F(2,386) = 1.68$, p = .188*	--	--	--
Length of sleep	$F(2,386) = 4.09, p < .05$	$p < .05$	$p < .05$	$p = 0.956$*
Quality of sleep	$F(2,386) = 5.02, p < .05$	$p < .05$	$p < .05$	$p = 0.970$*
Nighttime sleep duration	$F(2,385) = 0.15$, $p = .865$*	--	--	--
"How feel" in morning (alertness)	$F(2,386) = 4.49, p < .05$	$p < .05$	$p < .05$	$p = .970$*

* Not significant at $p < .05$

Table 25. Alertness and sleep disorders (workdays only)

	Untreated Sleep Disorder	Treated Sleep Disorder	Normal
Upon awakening	2.7	3.5	3.5
After commute to work	3.0	4.0	3.7
After lunch	2.7	3.9	3.7
After arriving home	2.3	3.5	3.2
At bedtime	2.0	2.4	2.5

Table 26. One way ANOVA and post hoc (Sheffe's) comparisons by sleep disorder status for alertness at various times throughout the day

Variable	ANOVA	Untreated versus Treated	Untreated versus Normal	Treated versus Normal
Upon awakening	$F(2,386) = 3.68, p < .05$	$p = 0.062$ *	$p < 0.05$	$p = 0.981$ *
After commute to work	$F(2,386) = 5.11, p < .05$	$p < 0.05$	$p < 0.05$	$p = 0.271$*
After lunch	$F(2,386) = 6.89, p < .05$	$p < 0.05$	$p < 0.05$	$p = 0.357$*
After arriving home	$F(2,385) = 5.88, p < .05$	$p < 0.05$	$p < 0.05$	$p = 0.393$*
At bedtime	$F(2,383) = 1.55$, $p = .213$*	--	--	--

* Not significant at $p < .05$

3.5.6 Sleep Characteristics Summary

Signalmen get less nighttime sleep than U.S. adults on workdays but get more sleep on planned days off. While 39 percent of U.S. adults get less than 7 h of sleep on workdays, over 50 percent of signalmen have this amount of sleep. Total daily sleep, which includes naps as well as nighttime sleep, for both construction and non-construction signalmen, is about 1 h longer on planned days off than on workdays. Naps on planned days off are slightly longer than on workdays. Nearly half of all naps begin between 2–6 p.m., which corresponds with the circadian nadir making it a convenient time for naps. This time period also follows the end of the workday for many signalmen.

While both groups of signalmen get about the same amount of daily sleep, construction signalmen rated their sleep of higher quality than the non-construction group on both workdays and planned days off. This is likely due to disrupted sleep resulting from nighttime emergency calls that the non-construction group must handle. Both construction and non-construction signalmen gave higher ratings to their sleep on planned days off than on regular workdays.

Construction signalmen rated their work night sleep at home of higher quality than the sleep they get when away from home, although the duration of their nighttime sleep is shorter at home.

Signalmen with diagnosed but untreated sleep disorders rated their sleep of lower quality and had lower alertness ratings throughout the day than those with treated sleep disorders or no sleep disorders.

3.6 Textual Analysis of Work and Sleep Comments

The signalman's daily log included two separate spaces for participants to record any comments regarding their sleep and work periods each day. This section presents an overview of participants' comments on their sleep and work experiences throughout the 2 weeks of the study.

Commenting on sleep or work experiences in the daily log book was not a requirement of participation. Rather, these sections of the log book gave participants an opportunity to qualify part of their day. As such, some participants chose not to comment, while others commented frequently. For this reason, a statistical analysis of these comments was not possible. Researchers scanned a number of participant log books to determine common themes presented in the comments and performed a simple tabulation of the frequency of topics mentioned. The following themes emerged from this review:

1. Fatigue (physical fatigue, being sleepy, worn down, sore, etc.)/alertness (mental alertness, vigilance)
2. Unscheduled work (asked to work early, stay late, work off days, overtime)
3. Travel (related to commuting to/from work or lodging)
4. Weather
5. Personal issues (family, leisure activities)
6. Stress
7. Sleep location (related to sleeping at home or away from home)
8. Safety
9. Management
10. Territory
11. Dispatcher, track gang, track crew, track department
12. Responsibility
13. Job security

Researchers used ATLAS.ti® software V5.0 to autocode the comments based on keyword searches and tally the number of comments made under each topic area. Table 27 lists the keywords that were the basis for each topic area search.

The most frequently mentioned topics from the sleep comments experience were fatigue, personal issues, and unscheduled work. Comments on unscheduled work, travel, and fatigue dominated the work experience section. The comments complement the quantitative survey results by providing personal examples that the effect of work or sleep patterns present in the

Table 27. Keywords used for each topic area search

Topic	Keywords
Alertness (mental)	Alert*, aware*, awake, attentive*, watchful, vigilant, prepared
Dispatcher, track gang, track crew, track department	Dispatcher, track gang, track crew, track department
Fatigue (physical)	Fatigue*, tired, sleepy, exhaust*, spent, weary, energy, weak*
Job security	Job security, secure*
Management	Manage*, boss, supervis*, company, policy, organization, administration
Personal issues (family, etc.)	Personal, private, family, domestic, son, daughter, wife, kid*, baby, father, mother, grand*, relative*, child*
Responsibility	Responsib*, duty, blame, reliab*, accountab*
Safety	Safe*, accident, incident, injury, casualty, error, protection
Sleep location	Bed, hotel, motel, away, camp*, camp car, noise*, room*, lodging, accommodation*, quarters
Stress	Stress*, workload, work load, pressure, too much, strain, anxious, anxiety, worry, tense
Territory	Territory, coverage, area, region
Travel	Travel, commute, driv*, drove, worksite, trip, car, truck, camper
Unscheduled work	Schedule, overtime, call*, night call, weekend call, emergency, unscheduled, shift work, respond, crisis, trouble
Weather	Weather, heat, hot, degrees, temperature cold, freezing, wet, rain, snow, sleet, light*, dark, sun, ice, climate, condition*

***Note:** ATLAS.ti search logic uses the symbol "*" as a wildcard. For example searching for "stress*," would result in all words starting with s-t-r-e-s-s, and would include any ending (such as stressful, stressor, etc.).

survey data. Perhaps more important is that many comments touch on a topic not explicitly addressed by the survey. In this way, the comments provide a more complete picture of signalmen's fatigue-related concerns.

Table 28 presents more detailed results of keyword searches. The table combines the topics of fatigue and alertness due to relatively few comments on alertness.

Table 28. Frequency of comments by topic area and source

	Source of Comments		
Topic	**Sleep Log**	**Work Log**	**Total**
Fatigue/alertness	219	187	480
Unscheduled work	107	362	469
Travel	46	237	283
Weather	16	180	196
Personal issues	111	49	160
Stress	19	132	151
Sleep location	80	15	95
Safety	8	73	81
Management	4	46	50
Territory	1	38	39
Dispatcher, track gang, track crew, track department	0	19	19
Responsibility	1	4	5
Job security	1	1	2
Total	**648**	**1382**	**2030**

The selected comments that appear below illustrate the consequences of the work and sleep patterns in the survey data. For example:

- Most of the fatigue comments relate to fatigue resulting from travel, unscheduled work, and poor sleep.
- Many participants reported unscheduled or emergency work and often mentioned disrupted sleep as a result.
- The travel comments illustrate how travel to a distant work site can lead to fatigue in addition to compromising personal and sleep time.

- Comments with regard to weather illustrate that survey participants frequently felt that weather affected their perceived level of fatigue and the overall quality of the workday experience.
- Some survey participants described personal situations that affected their sleep.
- Comments with respect to sleep location address difficulties encountered when sleeping away from home.

Selected comments by topic follow:

Fatigue/alertness

- "Went to bed at 10:00 p.m. and was called out to work at 10:45 p.m. On my drive home, I had to stop the truck and walk around it 4 times to keep from falling asleep while driving. I cannot sleep when the sun is up."
- "My sleep was interrupted by railroad calling at 0245. Too tired to take call."
- "Tired, not enough sleep, only 3 hours and 45 minutes. However, I was fully rested according to the hours of service law."
- "Asked to report to test at 0600. Work most of the day. Called it quits due to rain. Called back into work after a hard day of work at home. Called at 1930 to a case of trouble. One hour, 30 minute drive to and from problem. Now the drive home is a killer. Very tired and I only get 8 hours of rest before I have to be back to work. But it's not 8 hours rest because I have to be back at work by 8 hours. It turns out to be about 6 hours. It'll be a rough day tomorrow but they will expect me to be at the top of my game."
- "Just another day on the railroad. … tired because of a sleep schedule that never stays the same."
- "No one else available. Took calls …170 miles away. When I finally got done, was very sleepy on the drive home. Stopped at … rest stop, nap for 30 minutes in the front seat of truck. Uncomfortable. Then stopped … for 15 minutes. Sleepy at wheel, then at home."
- "Often, on the first day of a work stretch, you are extremely tired because of the long drive that you need to make to report to your work location. This time, I only had to drive 300 miles, but in the past, I have had to drive almost 800 miles which resulted in my feeling sleepy for 2 or 3 days."
- "Today was tough. I was tired all day. I got about 2 and a half hours of sleep before getting called back into work. After I got home and got cleaned up it was 0330 before I was able to go to sleep. I guess I got about 5 hours of sleep but it was interrupted. While working with MOW crew I had a bad headache and my eyes were dry most of the day. I wasn't looking forward to working overtime but I was glad to go on the hours of service (until 0100). I just hope they don't call me at 0115. They are real good about doing that. Control center did call last night at 1:30. I slept through it (ignored is more like, I wouldn't have been able to make it)."
- "I was called at 12:30 a.m. I drove 77 miles to put in a light bulb. On my way back home I had to stop and sleep on the side of the tracks because I couldn't keep my eyes open."

- "Drove … from home. Drowsy, almost fell asleep 3-4 times. Woke up when I hit the rumble strip on the highway."

Unscheduled work

- "This is a typical call schedule. I go to bed at normal time and then I get called out with just a few hours sleep. When I get to sleep it's in the daylight hours and I really can't sleep at that time."
- "'Night before' calls always affect my 'next day' alertness."
- "An early morning "call out" at 0030 tends to screw up the whole day. My sleep schedule is out of whack and this makes for a long, tired day. Drink a lot of coffee."
- "No calls. Life is good. Where were you in April, May, and June? When I had back to back Production Tie Gang (2500-3000 ties a day), 2 Production Surfacing Gangs and a Production Rail Gang. I worked 10-12 hours a day, 6 days a week with little help and took numerous after hours trouble calls. I spent July and August trying to recover from the mass destruction (many more trouble calls) and catch up in general. I know that the study was only recently implemented, but I wanted to point out that the 2 week window I submitted does not come close to representing the normal life of a signal maintainer. October and November are the quietest months of the year for us. The weather is perfect (weather is everything for the signal department), and the production season is at or near an end. That is why I just came back from vacation. I think a followup study during the spring storms would paint a different picture."
- "… I wanted to point out the worst case scenario that happens too often. The Hours of Service law allows that we are 'fully rested' after being off duty for 8 hours. The majority of our members work regular hours, basically 0700-1530. If they knew they were going to be called out at 2330 or shortly after that, and work 12 hours, then they could go home and get some meaningful rest. They don't know that and never will. Numerous times we are called at 2330 and have to work 12 hours then travel home without having any sleep after the previous night. Too many times the railroad purposefully waits to call at 2330 because they know, according to the law, you are rested. I worked the Trouble Desk for 15 years."
- "The problem with the study is that I will go a week sometimes without many calls. But in bad weather times with rain or snow, it could be every day. Or like the day I just recorded. I went to sleep at 2330 and was called out 0300, 3 and a half hours of sleep. I get home at 0700, fall asleep for 2 hours but wake up because of daylight, and I just don't sleep easy in daytime hours. So 8 hours of supposed rest goes by, and I get called out and have to make sometimes a one and a half hour drive."
- "The reason I am on a zone construction gang now is the fact that I could not handle all the late night calls that I experienced when I was working as a maintainer. The maintainer districts are long, and there is not enough coverage, and relief is usually not available. It seems that the maintenance manager's sole purpose is to keep the budgets cut to a minimum instead of supporting the maintainer districts properly and staffed with a reasonable amount of manpower."

- "Took calls 160 miles from home. Got back to within 30 miles of home and another call 125 miles from home. Then another call before I got finished. Got to my 2 hours and signed out. Let management take care of other problems. No one else around for weekend."
- "Trouble call 0215-0600. Slept at headquarters on account of 0700 start time for regular assignment."
- "You'll notice that my daily work/sleep log appears somewhat boring. So I feel compelled to explain. If I could have taken this survey back in 1996, it would have been a real eye-opener. I was a field signal maintainer for over 17 years. During that time, I cannot tell you how many thousands of times I was called out on trouble calls at all hours of the day and night (usually about 0100! Really!). At first it seemed like high adventure and I was really saving the railroad. But after the years went by and thousands of calls later, missed holidays, missed sleep, walking around in a half-daze, it became unworkable, so I bid over to the construction side of signal. I still work very hard and give the company an honest day's work. But I rarely get called out anymore, and life is better. Just thought you'd like to know. By the way, I've always kept a personal log/diary all my career. I still have a history of all those years as a maintainer!"

Travel

- "Drive to [work location]. Leave late so as to not rob the family of time. 460 miles. Begin 8 ten-hour day session."
- "Mondays (or first day of week) are long days for me as I have to drive 135 miles to my headquarters."
- "Often, on the first day of a work stretch, you are extremely tired because of the long drive that you need to make to report to your work location. This time, I only had to drive 300 miles, but in the past, I have had to drive almost 800 miles which resulted in my feeling sleepy for 2 or 3 days."
- "Drove home from hotel after work shift ended, 348 miles."
- "Planned day off but gang employees are required to drive from their homes to a hotel near their job location on their time with no compensation. …348 miles = 6 hours. Left home 1700, arrived 2300."
- "Signal testing, testing, removing old cables, installing new cables, terminating, and more testing. Working overtime. 11 hours on duty and 11 hours off duty but with a 3 hour commute included in the 11 hours off time."
- "Drove for 3 hours to get to location. Worked for one hour then traveled to next location. Worked for one hour then traveled for 4 hours home."
- "Traveled for 2 hours on my rest day to get ready for next day of work."

Weather

- "The worst part of being a maintainer is that there is an hour and a half drive and that we are working in the cold. It is 10 below zero tonight. I get into the warm truck and try to

drive the hour and a half home. I need to nap a bit to make it. And it is a struggle to work alert the next day!"

- "Between the heat (84 degrees), the digging, working a 12-hour shift, and the travel time, I was so tired today."
- "Rainy and cold weather has me feeling tired."
- "The weather outside was cold and humid, causing a greater loss of energy, making me feel so fatigued now."
- "Today's weather was very dismal and created a poor working mood. The short nap I had earlier was very needed."

Personal issues

- "So tired I could not sleep. Thank goodness the baby slept all night and I did not receive a call-out. It's been 12 days since an 'off' day for me, and it is really catching up."
- "Had very restless night. Woke up 3 times due to wife being sick, dog barking. Did not get much sleep. Feel tired and exhausted, mentally and physically."
- "In order to see my family I go home if I can during my work period. Eight days is too long to be away from my home and my family. Sleep was minimal due to one of my kids being sick during the night."
- "Had trouble all night trying to sleep. Worried about my son in Iraq, 2 killed in his unit today."
- "Hard to get to sleep, lot on mind: job and family."
- "I've had a cold all last week and weekend. With no personal days and not wanting to waste vacation time, it's very hard to shake it off. Plus, I have worked a lot of OT, and it's been raining a lot. My cold is getting worse. Tossed and turned all night."
- "Sick 4-month old baby is the reason for all the awakenings and poor quality of sleep."
- "Would have liked to have a power nap but evening was filled with [son's] violin recital and spending time with wrestling clinic and kids. What;s new!"
- "Long day. Lots of walking, climbing, carrying. Not too much real physical labor. After work still had to come home, fix dinner, feed kids, and have some quality time with 3-year old."

Stress

- "Could not sleep, too stressed out about Monday cutover. Lots of coffee today!"
- "Didn't sleep well due to stress about job."
- "Worked around MoW track gang fixing wires that were broke by their equipment. These kinds of days are very stressful because you have to make sure you hook up all the wires correctly or you could get yourself in trouble."
- "Being the foreman, not especially a lot of physical labor done but stress with other crafts and job tasks, decisionmaking, etc."

- "Had lot of pressure today to get job done fast. Hurry, do this and that. Worry if everything done right."
- "On-track safety rules are the most unworkable rules ever shoved down our throats and cause us more stress than any other single factor, especially the foul time within interlocking rule because I always work alone and I am always within the interlocking limits. This causes me great stress."

Sleep location

- "Staying in a noisy motel with a hard mattress made for an uncomfortable night even though I was tired."
- "As always, sleep at home is so much more rewarding than being in a low rate motel that [railroad] says is perfectly fine?!#@#!"
- "I usually don't sleep well the first night away from home with the strange bed and surroundings."
- "It's hard to tolerate noisy motels, poor quality beds, and inconveniences. Someday [railroad] will treat us as humans!"
- "Noise at motel. Near tracks, trains, other guests."
- "Very hard to sleep well in a hotel bed away from family."
- "While working construction, sleep or good sleep often depends on how good the motel is. [Railroad] seem to be putting us up in cheaper and dirtier motels all the time. This is a problem that needs to be addressed."

Safety

- "Sleep has been erratic since beginning work on the third shift. But at least I am fortunate to be in a safe work environment. I know from experience that shift work for employees working on the right-of-way in a fatigued state is hazardous."

Management

- "Have trouble sleeping. Supervisor pain in the butt, 'Mr. No Money.'"
- "Had bad dreams. A lot of stress at work with general supervisor. Kept waking up."
- "Very rough sleep. Was to meet with manager and supervisor. Would I be able to answer questions? Stress HIGH."
- "Once again, not enough people on crew to handle job correctly. Shortcuts and hurry up procedures are normal to make foreman and supervisor look good. Railroad workers do not matter one bit to stockholders!"
- "Planned work changed again. At 0730 was briefed for work, and at 0830 plans changed by management."

Territory

- "Stressful. Overtime call was on another territory other than mine. Was there until 1130 not knowing what is going on around my territory."

- "Trouble on neighboring maintainer's territory. He's on vacation, and the company does not relieve maintainers. Just a lot of extra work. No time for lunch break or any breaks."
- "A lot of cranking switch machines. Doing FRA testing with machines and signals. At times when I can't get time from the dispatcher with the large territory I have, it gets very stressful. Especially when it gets to the end of the month. All the testing is monthly testing, and I have to make sure that all the testing is done before the end of the month. Sometimes with all the pressure I do get them done to the best of my ability and safely."
- "With the territory I have its hard not to get stressed out. There's one guy that outlaws early. Usually there might be problems at one end of my section, it takes maybe one hour to get there, and they wonder what takes me so long. Traffic on the road; try to stay within the speed limits. Then when I need parts it takes me a lot longer. Then when I get it done I am all stressed out. Then I take it out with my family when I get home. Not all the time."

Dispatcher, track gang, track crew, track department

- "A lot of stress as to dealing with public with crossing being activated. Account of megging cable at high traffic area. Then, dealing with a dispatcher that is hard to work with."
- "Had problems today getting track protection from dispatcher. We will have to go back tomorrow and finish what we should have been able to do today."

Responsibility

- "Woke up 2 times last night, had work on my mind. Much to learn as new maintainer with much responsibility now."
- "I just recently started a new signal maintenance job. Getting adapted to the new position and responsibilities is very stressful and exhausting."

Job Security

- "Not restful. Spent time with concern about work and future job."

4. Findings and Recommendations

Analysis of the data from this study provides some insights into the demographics of the signalman population, as well as how their work schedules and sleep patterns affect their alertness on the job. Because the data was taken from a random sample of the U.S. signalmen population, the results are representative of the nation's signalmen population at the time of the survey. Because the data collection occurred at what appears to have been a period of relatively lighter workload, the observations and conclusions regarding work schedules and sleep patterns would likely have been more pronounced had the survey occurred at another time of year.

This section presents the key findings of the study, as well as some recommendations for methodological changes for future field studies of this nature. The section concludes with some suggestions for additional uses of this data.

4.1 Key Study Findings

The following subsections highlight the key findings with respect to the signalmen's nominal work periods, unscheduled work periods, and sleep patterns.

4.1.1 Work Periods

The nominal schedules for both construction and non-construction jobs have 80 h of work in a 2-week period. The workday for a construction job is usually 7 a.m. to 5 p.m. Half of the construction signalmen work 4 d per week, and the other half are divided between 5-d weeks and 8 d on followed by 6 d off. The workday for non-construction jobs is typically 7 a.m. to 3:30 p.m., 5 d per week. Both types of signalmen tend to work more hours than their nominal schedule. This extra work is due to overtime periods and, for non-construction signalmen, primarily unscheduled work periods. The mean number of hours worked by construction signalmen was 83:16 during the study period while non-construction signalmen worked 87:32. These results do not indicate excessive overtime. However, 25 percent of the construction signalmen worked more than 88 h, and 25 percent of the non-construction group reported working more than 92 h. This means that a quarter of the construction signalmen worked at least 1 d of overtime, and a quarter of the non-construction group worked at least 1.5 d of overtime in the 2-week period.

The average overall length of the workday, including commuting and lunch breaks, was 10:11 for non-construction jobs and 11:25 for construction. Both workdays allow adequate time for nighttime sleep. Because the majority of construction jobs require lodging away from home, these signalmen do not have competing family and person obligations while away. For this reason, they should be able to get adequate rest in spite of the substantial part of their day devoted to the job. In contrast, the nighttime call of non-construction signalmen, who tend to have a shorter workday, likely prevents them from getting adequate and restful sleep when they are called.

The work schedules for construction jobs are less variable than those for non-construction jobs. Only 10 percent of the signalmen working construction jobs experienced start time variability of 1 h or more on any workday during the study. In contrast, 27 percent of the other jobs had at least 1 d when their workday began either 1 h earlier or 1 h later than the prior day. The

variability of the non-construction signalman's work schedule is likely responsible for their lower alertness levels throughout the work day.

4.1.2 Unscheduled Work Periods

The average signalman working a non-construction job had 1.9 unscheduled work periods per 2-week period of the study. Nearly two-thirds of the study participants were called back to work at night or on a weekend at least once during the study period. Morning alertness following a callback was significantly lower in comparison to mornings when no callback occurred on the prior day. While the difference was statistically different, the effect size was small. This result implies that other factors contribute to morning alertness and that eliminating unscheduled work periods would not substantially improve morning alertness.

4.1.3 Sleep Patterns and Alertness

Both groups of signalmen get the same amount of nighttime sleep on workdays, but this amount is significantly less than the norm for U.S. adults. On planned days off construction signalmen are getting on average 10 min more sleep than those working non-construction jobs, but both groups average more than the U.S. adult norm. Not only is weeknight sleep significantly less than U.S. adult norms, but the percentage of signalmen getting less than 7 h of sleep is also significantly greater. This is a concern since research has shown that performance decrements occur with less than 7 h sleep, particularly if it is consistently at this level. Even more disconcerting is that 16 percent of signalmen are getting less than 6 h of nighttime sleep on workdays, and these individuals, who perform safety critical jobs, are probably unaware of the extent of their performance degradation.

While both groups of signalmen get the same amount of daily sleep, some differences exist in the quality of that sleep and their reported alertness. The non-construction group rates their sleep of lower quality than the construction group. This is likely due to split sleep resulting from nighttime call. The non-construction group appears to use naps as a way to compensate for lost nighttime sleep. Both groups get the same amount of daily sleep and work nearly the same total hours weekly, but the non-construction group reported lower alertness. Start time variability and unscheduled work periods are, at least in part, responsible for this.

The incidence of reported sleep disorders among signalmen exceeds the U.S. adult norm for sleep apnea. Because of the wording of the question on the background survey, it is not possible to determine if all of these signalmen have sleep apnea. For this reason, it is not certain that the incidence of sleep apnea in this population exceeds U.S. norms. Given that those with diagnosed but untreated sleep disorders were significantly less alert than the non-sleep-disordered population, however, it is likely that these people have sleep apnea. Railroads and unions should continue their education programs pointing out the possible performance consequences of untreated sleep disorders. Those with untreated sleep disorders should be encouraged to seek treatment.

4.2 Recommendations for Improvements in Study Procedures

Based on the experience of this study, several methodological improvements should be a part of any future studies to collect work schedule and sleep pattern data. The recommended changes are the following:

- *If the study population includes workers who must travel long distances on their own time to reach the rally point or lodging site, the daily log should have a place to enter this data.* Failure to include this in the daily log for this study was an oversight.
- *The background survey should inquire whether or not the participant has been diagnosed with sleep apnea, as well as a sleep disorder, so that the results can be compared with U.S. norms for sleep apnea from the Wisconsin Cohort Study.* A question on sleep disorders is also necessary to be certain that poor sleep due to a sleep disorder does not confound the survey data.
- *If possible, data collection should occur at a time of year that has a typical workload.* Unfortunately the OMB approval process delayed the start of the data collection for this study. Data collection was originally scheduled for the summer months.
- *The data collection period should avoid daylight savings time changes and holidays.* Because mailing of the survey materials occurred in mid-October, some participants recorded data over the weekend when daylight savings time ended. As a result, adjustment of this Saturday night sleep time was necessary for participants who recorded data at this time. The data collection period did not include any holidays. Future surveys should avoid holidays because a full 2-week work cycle would not be possible with a holiday.
- *Future studies should include instructions to not collect data during a vacation period.* The instructions for this study asked participants to begin data collection at the start of the next work cycle. There were no specific instructions to avoid collecting data during a vacation period. A few people provided 1 week of data for a work week and 1 week of vacation data. The vacation data was of no use to the purpose of this study, which deals with the relationship between work schedules and sleep patterns.

4.3 Recommendations for Additional Research

A number of mathematical models exist for predicting human fatigue and alertness. The majority of these models have been developed using laboratory data on the human sleep cycle. A need for data exists on both work schedules and sleep patterns for further refinement of these models. In particular, the only data for railroad workers that has been available to date is from locomotive engineers. The availability of the signalmen data will allow the modelers to refine their models and to predict how the typical signalman work schedule may be affecting on-the-job alertness.

Finally, the analysis presented in this report characterizes the work schedules and sleep patterns of signalmen. Further analysis of the data could identify explanatory factors for the reported alertness levels. For example, the data indicates that a difference exists in morning alertness following a callback, but statistically the occurrence of the callback accounts for only a small portion of variance in alertness. Other factors, such as the length of the prior days' sleep periods and the time of awakening, could be explored.

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Appendix A.
Survey Materials

This appendix includes copies of the following survey materials:

- Letter to union members from union president
- Railroad Signalman Background Survey
- Signalman's Daily Log (1 full day)
- Instructions to participants on making entries in the Daily Log

Brotherhood of Railroad Signalmen

601 W. Golf Road
Mount Prospect, IL 60056

Phone: (847) 439-3732
Fax: (847) 439-3743

W. Dan Pickett
International President

Walt A. Barrows
International Secretary-Treasurer

<<Enter Date Here>>

<<name>>
<<street address>>
<<city, state ZIP>>

Subject: FRA Sponsored Fatigue Study

Dear Sister or Brother:

Fatigue is a major concern in our industry. The expansion of the Hours of Service Act, the erratic call-schedule of signal maintainers, and the workweek variations of signalmen produce an environment where fatigue can easily result.

As you may have read in *The Signalman's Journal,* the Federal Railroad Administration (FRA) and the Brotherhood of Railroad Signalmen are conducting a fatigue study that focuses on signalmen. You have been selected to participate in this very important scientific study. The results of the study will give the FRA and the BRS insight into the work schedules and sleep patterns of signalmen. The study will also provide the statistical basis required to identify any areas for improvements.

You are among a small group of randomly selected BRS union members nationwide that are being asked to fill out work/sleep diaries for a two-week period.

Your participation in this study involves:

1) completing a brief background survey and

2) keeping a daily log for 14 consecutive days of your sleep and work times along with self-assessments of your level of alertness five times per day.

To insure that your personal information is completely confidential, the FRA has engaged the services of Foster-Miller for executing the study. The names and personal information of the participants from the sample group will be completely confidential, and the data gathered will only be used to compile the information as a group. After the study's conclusion, all the personal data gathered will be destroyed and only the compiled information will be distributed.

Completing the background survey should take less than 15 minutes; making entries in the daily log should require no more than a total of 10 minutes per day. As a reward for your participation in this study you will receive a $75 gift certificate to either Home Depot or Sears. *You must provide 14 consecutive days of data and a completed background survey to receive the gift certificate.*

The overall purpose of the study is to develop a better understanding of the work/rest schedules and sleep patterns of signalmen and to evaluate the relationship between these schedules and fatigue. Your participation is critical to the success of this study. The data will allow us to identify any fatigue-related problems specific to our craft. Once we have the data, we will be able to work toward reducing the risk of fatigue-related errors in our safety-sensitive positions and improve the quality of life for our members. A report concerning this study will be published next year in *The Signalman's Journal.*

Please read the enclosed instructions carefully before beginning your data collection. Thank you for your participation in this important research study.

Fraternally,

W. Dan Pickett
International President

ID Number:_____

Railroad Signalman Background Survey

Form FRA F6180.107

About Yourself

1. Age: ____ years
2. Sex: ____ male ____ female
3. How long have you been a signalman?
   _____ years and ____ months
4. How long have you been a signalman at your current railroad?
   _____ years and ____ months
5. What type of signalman job do you currently work?
   ____ construction
   ____ maintenance (other than yard)
   ____ yard maintenance
   ____ other (please explain) _____
   _____
6. What is your marital status?
   ____ single ____ divorced ____ other
   ____ married ____ widowed
7. How many children or other dependents do you have (not including your spouse)? _____
8. How many of your dependents are under the age of 2 years?_____
9. a) Do you drink caffeinated beverages?
   _____ yes _____ no
   b) On average, how many cups and cans of these beverages do you drink per day?_____

Your Health

1. How many times have you called in sick in the last 6 months? ___ days

2. In general, how would you rate your health? Circle one:

   Excellent Good Fair Poor

3. Some people feel younger or older than their biological age. How old do you feel? ____ years

4. Have you been diagnosed as having a sleep disorder?

   ____ Yes ____ No (skip question 5)

5. Are you receiving medical treatment for this condition?

   ____ Yes ____ No

Your Work Schedule

1. Please describe your job characteristics.
   a) Circle the days you are scheduled to work over a two-week period:

      S M T W Th F S S M T W Th F S

   b) Start time _____
   c) End time _____
   d) Length of meal break _____ minutes

2. On average, how many hours do you work per week? ____

3. Do you file an FRA Hours of Service Report?

   ____ Yes ____ No

4. How often do you feel well rested and alert over the course of your work period? Circle one:

   Never Occasionally Frequently Always

5. How often do you feel physically drained at the end of your work period? Circle one:

   Never Occasionally Frequently Always

Stress at Work

Use the following scale to rate how much each factor below contributes to your stress at work:

No Stress	A Little Stress	Stressful	Very Stressful
1	2	3	4

Please assign a rating to *each* of the following items:

___On call schedule
___Responding to emergencies
___Lack of control over work schedule
___Loss of sleep
___Coordination with other departments
___Pressure to finish a job
___Ambiguous operating rules or procedures
___Management policies and decisions
___Travel to work site
___Job security
___Work rules
___Inadequate staffing
___Responsibility for safety of others
___Other (please specify) _____
_____

Life Events

Please indicate with a ✓ whether any of the events listed below has occurred to you in the last 6 months:

___Personal illness or injury

___Marital difficulties

___Birth of a child

___Death of a spouse

___Change in sleeping habits

___Difficulty with the law

___Illness/injury of family member or friend

___Financial difficulties

___Change in living conditions

___Change in social activities

___Death of a close family member

This collection of information is completely voluntary, and will be used for statistical purposes only. Public reporting burden is estimated to average 15 minutes per response, including time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Please note that an agency may not conduct or sponsor, and a person is not required to respond to a collection of information unless it displays a valid OMB control number. The OMB control number for this collection of information is 2130-0558.


Signalman's
Daily Log

ID Number_____

If you have questions, you can contact:

Sarah Acton
781-684-4281
sacton@foster-miller.com

Alex Viale
781-684-8444
aviale@foster-miller.com

FRA F6180.108

Welcome…
and thank you for participating in this project. The purpose of this study is to assemble data on both work and sleep patterns of signalmen. The data that you record will serve as a history of your work and sleep patterns and how you feel throughout the day. The study will examine the relationship between signalmen's work schedules and their level of alertness/fatigue.

Your participation is appreciated. Please contact us if you have any questions or comments.

Instructions

This log is divided into 14 sections, one for each day that you will be recording data. Each section contains both a Sleep and Nap Log and a Work Log.

Start a new section for each new day. On the section divider page, write the date and indicate whether or not this is a regular workday or a planned day off. Please start with Day 1. It is important that you provide data for 14 *consecutive* days.

When recording time, use the 2400 clock system. For example, 4:30 p.m. is 1630.

Complete the Sleep and Nap Log for *every* day of the study. Complete the Work Log for those days that you work.

If for any reason you do not record data at the appointed time, fill out your log as soon as possible to the best of your ability.

Sleep and Nap Log
Make entries on this log *upon awakening* and *at bedtime* ***every day.*** In addition, if you took any naps, enter this information in the log.

Work Log
Make entries on the work log at the *start of your workday* when you arrive at your workplace, *during your lunch break* and at the *end of the workday* when you arrive home.

You should use the *unscheduled work period* section of the log *only* if you were called back to work on a weekend or other day that is a planned day off, or on a regular workday after you left your workplace. If you did not work an unscheduled work period, then leave this section blank.

Study Compensation
Complete the last page of this log book to indicate your preference for the study compensation.

Day 1

Date _____/_____/2003

Today is: ❑ regular workday
❑ planned day off

Sleep and Nap Log

Upon Awakening

Sleep Location

Home ☐ Away from home ☐

Time you went to bed	
Time you fell asleep	
Time you woke up	
Time you got up	
Number of awakenings during the night	

Rate your sleep

Ease of falling asleep

1 2 3 4 5

Very difficult Very easy

Ease of getting up

1 2 3 4 5

Very difficult Very easy

Length of sleep

1 2 3 4 5

Wholly insufficient More than sufficient

Quality of sleep

1 2 3 4 5

Very poor Very good

Indicate how you feel now

1 2 3 4 5

Very sleepy Very alert

At end of day, if you took any naps

Nap 1

Time fell asleep	
Time awoke	

Nap 2

Time fell asleep	
Time awoke	

At Bedtime

Indicate how you feel now

1 2 3 4 5

Very sleepy Very alert

Comments on today's sleep experience:_____

Work Log

Start of workday

Time you began commute to work	
Time you reported to work	

Indicate how you feel now

1 2 3 4 5

Very sleepy Very alert

During lunch break

Time at start of lunch break_____

Indicate how you feel now

1 2 3 4 5

Very sleepy Very alert

End of workday when you arrive home

	hr	min
Longest time period you worked today without a break (A break is considered a minimum of 15 minutes of rest from work)		
Time you completed today's work period (Include unscheduled hours if there was *no break* between regular and extra work)		
Time you arrived home		

Indicate how you feel now

1 2 3 4 5

Very sleepy Very alert

After unscheduled work period(s), if any

Period 1

Time you were called to report back to work	
Time you reported back to work	
Time you completed unscheduled work period	
Time you arrived home	

Indicate how you feel now

1 2 3 4 5

Very sleepy Very alert

Period 2

Time you were called to report back to work	
Time you reported back to work	
Time you completed unscheduled work period	
Time you arrived home	

Indicate how you feel now

1 2 3 4 5

Very sleepy Very alert

Comments on today's work experience:_____

Survey of Work Schedules and Sleep Patterns of Railroad Signalmen

****Important: Please Read Before Making Entries in Daily Log****

Using the Signalman's Daily Log	The log is divided into 14 sections, one for each day that you will be recording data. Each section contains both a Sleep and Nap Log, and a Work Log. Start a new section for each new day. On the section divider page, write the date and indicate whether or not this is a regular workday or a planned day off. Please start with Day 1. Begin your log on the **first day of your next work cycle**. It is important that you provide data for 14 **consecutive** days. Complete the Sleep and Nap Log for **every** day of the study, not just your workdays. **We need a record of your sleep for all 14 days.** Complete the Work Log for those days that you work. If for any reason you do not record data at the appointed time, fill out your log as soon as possible to the best of your ability. The study results will not be meaningful without complete diary entries from you. Record times in the log using the 2400 clock system. For example, 4:30 p.m. is 1630.
Sleep and Nap Log (complete daily)	Make entries on this log **upon awakening** and **at bedtime every day.** In addition, if you took any naps, enter this information in the log.
Work Log (complete only for workdays)	Make entries on the work log **at the start of your workday when you arrive at your workplace, during your lunch break and at the end of the workday when you arrive home.** You should use the **unscheduled work period** section of the log 1) if you were called back to work on a weekend or other day that is a planned day off, or 2) if there was a break between the end of your regular workday and the start of your overtime. If you did not work an unscheduled work period, then leave this section blank.
Study Compensation	**You must return a completed background survey and 14 days of sleep and work schedule information to receive the compensation.** You will receive a $75 gift certificate to a retail establishment as compensation for your participation in this study. Complete the last page of the log book to indicate your preference for the study compensation. You should receive your gift certificate within 4 weeks of returning your materials.
Returning Study Materials	Return your Background Survey and Daily Log in the postage paid envelope.
Questions or Problems?	If you have questions on any aspect of these instructions or are not sure how to report specific work or sleep information, please contact us: Sarah Acton 781-684-4281 sacton@foster-miller.com Alex Viale 781-684-8444 aviale@foster-miller.com

Appendix B.
Adjustments to Data

Daylight savings time

Nighttime sleep duration was calculated by subtracting "time you fell asleep" from "time you woke up." On October 26, 2003, at 2 a.m., clocks were set back 1 h, thereby affording 1 extra hour of sleep. One hour was added to the nighttime sleep duration of those respondents who went to sleep the night of October 25 or before 2 a.m. the morning of October 26.

Total nighttime sleep versus naps

The survey instructions asked participants to record their nighttime sleep in the Upon Awakening section of the Sleep and Nap Log. If their nighttime sleep was disrupted due to emergency call or other circumstances, they were to use the Nap 1 section to record any subsequent sleep.

Since some of the entries in the Nap section of the daily log were in fact split nighttime sleep rather than naps, an adjustment to nighttime sleep was necessary. For workday entries, the researchers added any nap that began after "Time feel asleep" but before "Time you began commute to work" to nighttime sleep duration. This adjustment was not made for those who worked the night shift (defined as a start time between 6 p.m. and 1 a.m.) since these individuals could potentially have a legitimate nap after bedtime but before the commute to work. For nap entries on planned days off, if the nap began between 12 a.m. and 7 a.m., then the researchers added the nap duration to nighttime sleep duration.

The nap analysis did not include naps that were combined with nighttime sleep duration.

Data from vacation periods

Some survey participants collected sleep data during a vacation period. These data were not a part of the analysis of signalmen's sleep.

Unscheduled work periods

If an individual worked on a planned day off, the researchers treated the work period as an unscheduled work period. Hence, unscheduled work periods were counted not only for people who were called back to work after returning from their regular work period, but also for those who worked on a planned day off.

Work hours that were an extension of the regular work period were not treated as an unscheduled work period because the individual had not yet gone home.

Comparison of average hours worked with ASTE

Assessing the workload of the survey participants required a comparison of the average hours worked during the 2 weeks of data collection with a norm for signalmen in a typical year. The ASTE hours is a measure of the annual number of hours used as the basis for a signalman's compensation. By adjusting both the survey average and a recent ASTE number, a comparison is possible.

ASTE is computed based on the straight time hours that are used for signalmen compensation. ASTE reflects 1 yr of work. This includes time off (vacation, holidays, and time paid not

worked), as well as hours worked and overtime. This comparison assumes that all overtime hours are paid at time and a half.

The first adjustment to ASTE was to remove time off. Based on estimates provided by BRS, the researchers removed 88 h for holidays and 15 h for time paid not worked from the 2002 ASTE of 2763 h. The average vacation time for the survey participants, using each person's years of work experience and the current contract provision for vacations, was 151 h. This was also subtracted from the ASTE. The researchers calculated the adjusted ASTE as follows:

ASTE		2763
Average vacation	151	
Holidays	88	
Time paid not worked	15	
Total non-work h	254	
ASTE less non-work h		2509

Using 254 h = 6.35 weeks, the weekly adjusted ASTE is:

$$\frac{(2763-254)}{(52-6.35)} = \frac{2509}{45.65} = 54.96 \text{ h/week}$$

or 110 h in 2 weeks.

In order to compare the hours recorded in the survey logs, which are hours worked, with this adjusted ASTE, the researchers converted the survey hours worked to hours paid. The assumptions for this calculation were that (1) all hours worked beyond the nominal daily schedule and on planned days off were paid at time and a half and (2) any unscheduled work period of less than 2 h 40 min was compensated as if the individual had worked 2 h 40 min. This brought the 2-week hours paid for the survey participants to 94 h. This is 16 h less than the adjusted ASTE number. In other words, over the course of a year, signalmen are paid for 8 h more work per week than was observed during the study period. Since these 8 h represent straight time equivalent hours, the difference in hours actually worked is 8/1.5 or 5.3 h.

Population means versus mean of individual means

For some analyses of the daily log data, the researchers calculated a mean for each survey participant, and then performed the analysis with the individual means. The following measures were analyzed in this manner: actual hours worked (for 2 weeks), nighttime sleep by job type, type of day and job schedule; total sleep by job type; nap duration for everyone and by job type; sleep latency for all, by job type, and by type of day; and all data used in sleep disorder comparisons. For all other analysis of the data from the daily logs, the researchers used data from all participants without computing a mean for each individual. For example, the analysis of commute time was based on the mean of the data for all workdays in the survey data. This latter approach applied where it was desirable to characterize a typical day rather than the individual signalman's experience.

Abbreviations/Acronyms

ANOVA	analysis of variance
ASTE	average straight time equivalent
BRS	Brotherhood of Railroad Signalmen
d	day
FRA	Federal Railroad Administration
h	hour
min	minute
NARAP	North American Rail Alertness Partnership
NSF	National Sleep Foundation
OMB	Office of Management and Budget
REM	rapid eye movement
s	second
yr	year