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Identification of Fatigue Countermeasures for the Short Line Railroad Industry Phase 1 & 2

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Identification of Fatigue Countermeasures to Manage Fatigue in the Short Line Railroad Industry Phase I & II

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ABSTRACT

The purpose of the initial project was to establish a baseline for the evaluation of proposed fatigue mitigation efforts, to demonstrate the utilization of measures of sleep and fatigue, and to gather initial data for comparison to other previous studies. Results demonstrated that there was enough data to establish a baseline and to evaluate existing work schedules using the fatigue models approved by the FRA. Using the FRA approved modeling tool, a representative sample of work schedules were analyzed for likelihood of risk for fatigue related accidents using FRA recommended fatigue models. The results indicate that typical day time schedules have the least risk of fatigue. Standard night shifts working from 11 pm to 6 am had the greatest risk of fatigue. More importantly, by modifying the work schedules such that strategic naps were included in the work schedule on a regular basis, the models indicate that there is a significant reduction in fatigue risk that falls below or closely approximates the goal of ensuring that the work schedule does not "exceed the fatigue threshold more than 20 percent of the work time" recommended by FRA.

The two main fatigue countermeasures shown to be most effective were:

- Increasing the amount of sleep obtained between shifts.
- Instituting a scheduled workplace nap of either 60 or 90 minutes in length.

To reduce the accident risk associated with fatigue, the following countermeasures were considered most feasible:

1. Use of on-duty naps to offset the negative impact of midnight hours
2. Increase in the amount of off-duty sleep time
3. Increase the amount of on-duty supervision to recognize fatigue
4. Alteration of the start and end time of work shifts to avoid circadian rhythms
5. Decrease the number of hours worked

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EXECUTIVE SUMMARY

The Railroad Safety Improvement Act of 2008 significantly tightened the hours-of-service restrictions for railroad train crews. In response to some of these restrictions, the American Short Line and Regional Railroad Association (ASLRRA) and its over 400 members face considerable staffing challenges during annual peak harvesting season. Significant economic hardship, and advantage can accrue based on labor shortages. Consequently, concerns about working safely during these emergency periods were raised and the question of developing effective fatigue countermeasures was explored.

The present study explored the scientific feasibility of modifications to schedules and the effectiveness of fatigue countermeasures in reducing fatigue during these high demand periods. Baseline and comparison data were gathered that demonstrate 1) the fatigue effects of a consecutive six-day schedule will not have demonstrable or fatigue effects and 2) through the use of targeted fatigue counter measures, any possible effects of the schedules on fatigue can be mitigated sufficiently to warrant the implementation of the waiver.

For the Short Line rail Industry (See Figure 1.2), the majority of work shifts are day shifts and very few—only 16.6% of work shifts, start after 6 p.m. In addition, 76% of work shifts start between 4 a.m. and 4 p.m.

Depending on assumptions about the underlying nature of the shape of data distribution, the fatigue and accident risk extrapolated from previously reported data suggests that there are a number of possibilities in work schedules that can address the safety concerns of consecutive work days and how many consecutive days a person should work. The present discussion and additional analyses suggest that consecutive work days may have some relative risk of greater accidents, but that factors such as start times, work breaks, and other safeguards and mitigations may mitigate those risks.

Evaluation results of the fatigue countermeasures demonstrated that use of naps during the work period would result in a significant reduction in fatigue such that estimates of overall fatigue fall within the accepted and recommended fatigue risk levels. As can be seen in the appendices, specifically schedule "CP-002 – Actual" the fatigue mitigation counter measures modeled in the plots suggest that with the implementation of 60 or 90-minute naps significant reductions in fatigue could occur. The proposed countermeasures would be effective in managing the negative effects of fatigue. After reviewing the work schedules and operational demands of the baseline study participants, several suggested countermeasures were reviewed and considered. The operational practicality of these suggestions was reviewed by safety professionals working for the short line railroad association. The following countermeasures were considered most feasible:

- Use of on-duty naps to offset the negative impact of midnight hours
- Increase in the amount of off-duty sleep time
- Increase the amount of on-duty supervision to recognize fatigue
- Alteration of the start and end time of work shifts to avoid circadian rhythms
- Decrease the number of hours worked

1. INTRODUCTION

The Railroad Safety Improvement Act of 2008 significantly tightened the hours-of-service restrictions for railroad train crews. In response to some of these restrictions, the American Short Line and Regional Railroad Association (ASLRRA) petitioned the Federal Railroad Administration (FRA) for a waiver of the requirement that train crews remain off duty for one day after any period in which they work six consecutive days. The FRA granted the waiver petition in part, but did not extend the waiver to schedules, which extended into the midnight to 6 a.m. period, citing a lack of data concerning the fatigue implications of allowing workers who are on duty between those hours to return to work after only one day's rest following six days on duty. The present study will explore the scientific feasibility of modifications to schedules and the effectiveness of fatigue countermeasures in reducing fatigue during these high demand periods. FRA has made it clear that before it will extend the waiver to those time periods, ASLRRA must engage in a pilot project to generate data that demonstrates fatigue effects of working during those hours.

The present study gathered baseline and comparison data to demonstrate that 1) the fatigue effects of a consecutive six-day schedule will not have demonstrable or fatigue effects and 2) through the use of targeted fatigue counter measures, any possible effects of the schedules on fatigue can be mitigated sufficiently to warrant the implementation of the waiver.

1.1 Background on the Short Line Railroad Industry

Workforce work schedules were obtained from two companies that manage a number of short line railroads. Two companies—RailAmerica (RA) and WATCO—provided sufficient data to permit statistical analyses.

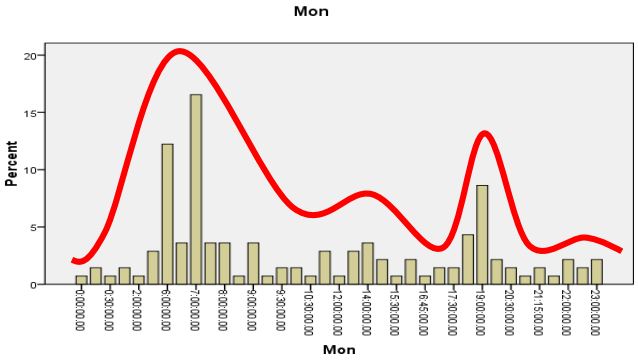

Figure 1.1 Start times for short lines

RailAmerica (RA) provided its entire work history for the 754 employees on its payroll in February 2011. The RA employees had 16,852 starts or days worked during that period. On the average, the RA employee had 22.35 starts during that time with an average length of shift equal to 9.48 hours and a standard deviation of 2.33 hours. The maximum hours reported working was 15.89. A little over 15.4% of the 754 employees reported working a shift over 12 hours during that time period. Data for WATCO companies are not as detailed. Much of the data was recorded by hand. Nevertheless, data was available for 22 different railroads, which consisted of work schedules for 204 different work schedules that 384 employees were assigned to—the actual number is uncertain due to missing data. Average shift length was not available for all railroads, but it was possible to determine that the majority of work periods

began and ended during daylight hours. Moreover, 75% of the work schedules were five days in length, 9% were six days in length, and 2% were seven days in length, the remainder worked four days or less.

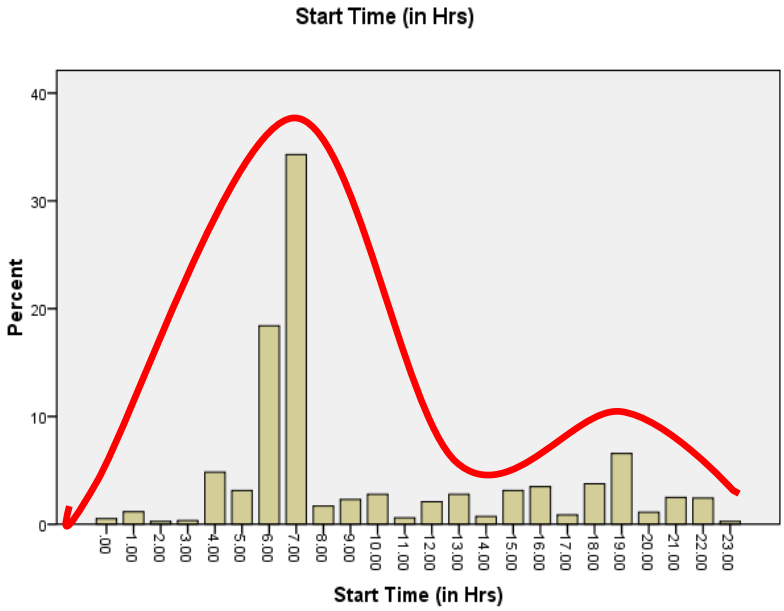

Figure 1.2 Rail America daily start time histogram

As can be seen from the graph (See Figure 1.2), the majority of work shifts are day shifts and very few—only 16.6% of work shifts, start after 6 p.m. In addition, 76% of work shifts start between 4 a.m. and 4 p.m.

Start Time (in Hrs)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.00	87	.5	.5	.5
	1.00	194	1.2	1.2	1.7
	2.00	45	.3	.3	1.9
	3.00	56	.3	.3	2.3
	4.00	814	4.8	4.8	7.1
	5.00	528	3.1	3.1	10.2
	6.00	3101	18.4	18.4	28.6
	7.00	5780	34.3	34.3	62.9
	8.00	283	1.7	1.7	64.6
	9.00	387	2.3	2.3	66.9
	10.00	469	2.8	2.8	69.7
	11.00	101	.6	.6	70.3
	12.00	352	2.1	2.1	72.4
	13.00	469	2.8	2.8	75.2
	14.00	123	.7	.7	75.9
	15.00	527	3.1	3.1	79.0
	16.00	588	3.5	3.5	82.5
	17.00	147	.9	.9	83.4
	18.00	634	3.8	3.8	87.1
	19.00	1106	6.6	6.6	93.7
	20.00	188	1.1	1.1	94.8
	21.00	420	2.5	2.5	97.3
	22.00	409	2.4	2.4	99.7
	23.00	44	.3	.3	100.0
	Total	16852	100.0	100.0	

Figure 1.3 Rail America start times for typical month

1.2 Schedules of Work

Based on these introductory analyses the workforce appears to work daylight jobs with only a small percentage (15%) working nights and weekends. Additionally, much of the existing workforce is working a 10 to 12-hour day five days a week. To provide a baseline for subsequent analyses of work schedules and comparison purposes, a sample of daytime and night jobs will be needed. Later, we can examine the change in fatigue and alertness levels between people who have been given somewhat longer work schedules.

2. LITERATURE REVIEW

Developing fatigue countermeasures for rail operations is based on the assumption that consecutive work days and long hours increase the safety and accident risk for people employed in and working in such jobs. An increased risk of accidents can pose a threat to the health and safety of the public. The Hursh et. al. (2006) model has been accepted by the FRA as a valid means of determining risk associated with work schedules. Previously, Hursh, et al. (2004) proposed the SAFETE model for evaluating risk for fatigue. The Hursh, et al. (2004) model has been accepted as valid by FRA however, t other sources of information and scientifically valid models can shed light on best practices for commuter railroad operations. Van Dongen (2004) concluded that "across four scenarios for which data were available to evaluate the models, not one model clearly stood out as the overall best or worst." (pg. A34) Interestingly, model predictions for the data, which consisted of 14 days of diary data from 10 extra board locomotive engineers, revealed that none of the models were much different from each other in predicting fatigue and explaining the data. However, it is interesting to note that one of the models that did fare slightly better in explaining data for this scenario was developed by Folkard & Akerstedt (1987, 1999).

Simply stated, different models may be needed to help understand and explain different types of phenomena, incident risk and work practices under consideration in the commuter rail environment. In particular, Folkard and Akerstedt have been very active in examining the issue of risk for injury associated with different types of work schedules. It is clear that their work should be consulted when making decisions related to these types of questions.

Folkard has worked extensively in the European Union and in the United Kingdom (UK) to assist in development of their Fatigue Risk Index (Folkard, et al., 2006, 2007), which is a model designed to predict accident risk associated with work schedules. The relative risk of accident ratios generated from seven published studies were used as the basis to develop the Fatigue Risk Index (FRI) used by the Health Safety Executive (HSE) in the UK. In the development of the FRI, only limited data were available on the relationship between number of days worked and accidents. The Folkard and Lombardi (2004) study was one of the preliminary reviews of the accident risk data and includes studies used to calculate and generate the FRI. There has been only one other major study subsequent to the Folkard review published by Dembe (2005) that also demonstrates a relationship (after analyzing self-report data) between work hours and accident risk.

2.1 Analysis of Fatigue Risk for Work Schedules

The data presented in Figure 2.1 are based on the average relative risk ratios calculated from the seven studies reviewed by Folkard et al. (2004) and referenced again by Hursh, et. al. (2006). Data from these studies are reproduced here for review and to demonstrate the cumulate effects of working consecutive days on relative risk of accidents. Data from these previously published studies were subjected to a trend line analysis and extrapolated over 30 days. Several assumptions must be made to extrapolate. First, one must make an assumption about how the data are shaped. In other words, is it safe to assume that the data are progressing linearly or through some other type of process such as exponential or an even more unique polynomial progression? These different approaches provide different results. Note the shape of the various lines or curves presented in Figure2.1, which summarize results of the seven studies used to formulate the FRI relative risk index and to generate the mean for the seven studies on which the FRA extrapolations were based.

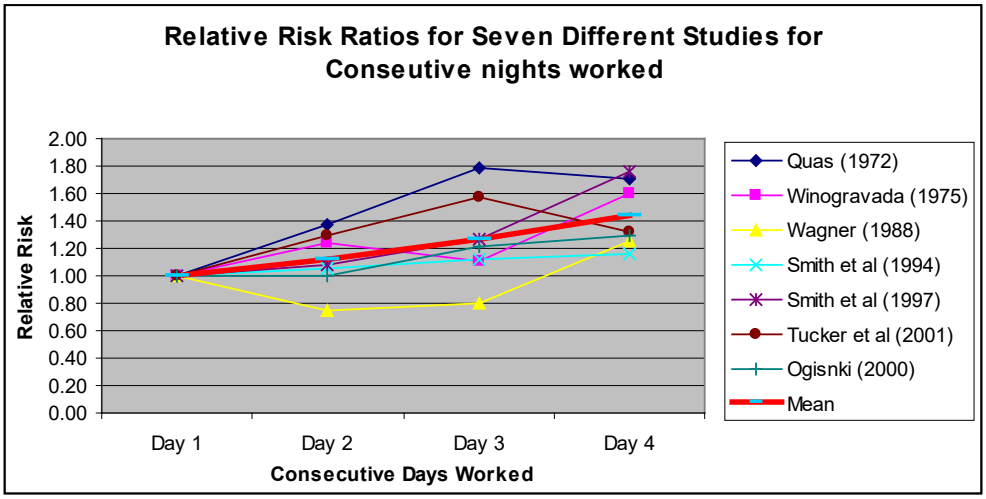

Figure 2.1 Relative risk ratios

In Figure 2.1, data on which the proposed extrapolations are based are provided. It is fairly obvious that not all of the lines are rapidly trending upward in a typical J-shaped or exponential fashion. Some go up in a linear fashion (Ogisnki, Smith), some stay relatively flat (Smith, 1994), and one, the Wagner data, are in a traditional U-shaped form. At this point, given the limited data available for only four consecutive work periods, the fact that both a linear, exponential, and polynomial function account for 99% of the variance with differences between the solutions of only about 0.68% (.9982 - .9914) suggest that all are roughly equivalent. However, in most cases, by inspection, the shape of the data is linear. All things being equal and using the principle of Occam's razor (Merriam-Webster, 2010) or what is known as the law of parsimony, the more conservative and appropriate approach is to assume that the data behave according to a linear function.

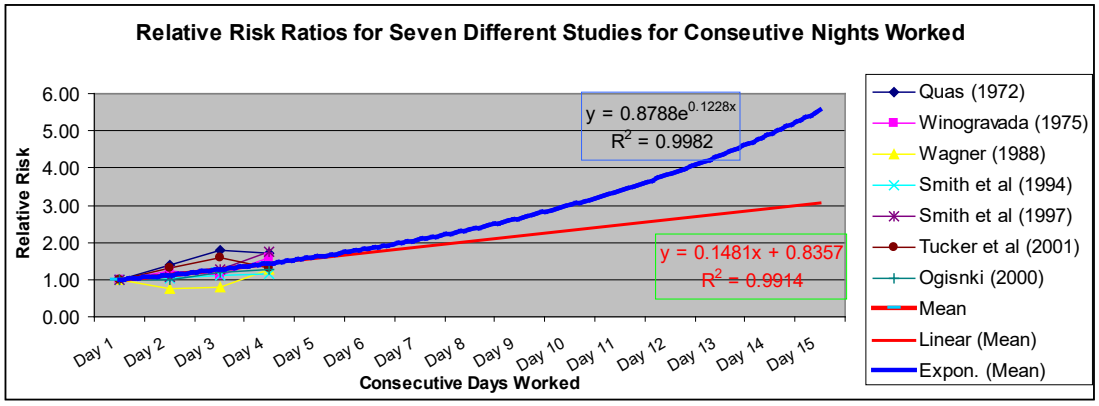

Figure 2.2 Comparison of linear versus exponential curves

Figure 2.2 demonstrates that using different assumptions about the underlying shape of the data can result in different conclusions about the degree of risk associated with different schedules and the effects of consecutive days worked, fatigue and accidents. The Hursh, et. al (2006) results were replicated (blue or top curve) in our analysis using an exponential function to generate a trend. However, a similar analysis can also be conducted based on a linear view of the relationship. Thus, the basic question is: which approach or type of function is correct? Different assumptions lead to different conclusions. The authors of the study from which these data are derived used the data to develop the Health Safety Executive

(HSE) Fatigue Risk Index. In their discussion of the data used to generate the average relative risk ratios (RR) they note:

> The estimation of the increase in risk on consecutive shifts has been based on the relative risk data over four successive nights (Figure B-4) and day (Figure B-5) shifts. The increase is reasonably approximated by a linear trend, representing an increase of 0.0562 over each consecutive day shift and of 0.1207 over each consecutive night shift. (Spencer, Robertson, & Folkard, 2006, pg. 57) (Underlining added, Figures B-4 and B-5 are in the original article and not reproduced here).

Similarly, Folkard & Lombardi (2004) also looked at the relative risk data for both day and night shifts and concluded:

> The relative risk data (Folkard and Lombardi, 2004) and the Risk Index suggest a fairly linear increase over spans of successive night shifts. Finally, all the day- and night-shift values were combined together into a single analysis. The R^2 for the best-fitting linear regression between the two datasets of 40 values was 0.83 ($p<0.001$). (Folkard and Lombardi, 2004, pg. 1070)

Thus, they argue for an underlying linear relationship. It should be noted that additional empirical data is needed to determine which approach (linear or exponential) is correct. Admittedly, four successive nights is not much on which to base an extrapolation. Inspection of Figure 2.2 reveals that most of the curves increase linearly. However, implications of the assumption are that risk increases from RR of 2.5 with the linear model or 4.5 with the exponential model at day 13. The predictions for six consecutive days are roughly equivalent and show that there is a negligible difference between the two approaches to calculating risk using the extrapolation approach, which finds relative risk of injury after a six-day schedule to be approximately 1.68. Unfortunately, that is considerably higher than the estimates of relative risk ratios generated by the FRI, which show RR=0.82, 1.07 and 1.16 for daylight, swing and midnight shifts respectively.

One additional point is regarding the use of a simple extrapolation from the four successive-day relative risk data. The extrapolation does not take into account the differing start times, duration of duty, rest breaks, and naps that also affect the fatigue and relative risk of an incident. A model that attempts to include all these factors is likely more accurate that a simple univariate estimate.

Folkard and colleagues developed the FRI using the linear additive approach combining different estimates of fatigue, which was first adopted by the UK Health Safety Executive in 1999 and revised in 2006.Their model attempts to estimate the RR of an accident through a linear combination of data from the following main parameters: length of shift, time of day, number of breaks, and number of consecutive shifts. The FRI generates estimates of fatigue and relative risk of incidents. The Risk Index has been normalized such that if a rotating work schedule is repeated over a 24-week period that risk of an incident is equal to 1.00. A typical rotating schedule is assumed: two days on, two nights on, four days off. In addition, the index assumes that: shift changes occur at 07:00 and 19:00; typical commute time equals 40 minutes; the work is moderately demanding in terms of vigilance; a rest break is taken every two hours; and that the longest a person would work without a rest break would be four hours with a 30-minute break. The FRI manual lists several assumptions and cautions regarding the use of the model. The authors urge caution in using the FRI with permanent night shift workers since research suggests that a small percentage of permanent night shift workers may have a positive adjustment to the night shift. They note that the Fatigue Index for permanent night shift workers might be "over-restrictive for the significant minority (about 30%) of permanent night workers who are likely to

show some adjustment of their circadian rhythms. These individuals could probably work a substantially longer span of successive night shifts without suffering any major ill effects in terms of fatigue and safety." (Spencer, Robertson, Folkard, 2006, pg. 66)

Caution must also be used in applying the FRI to commuter rail operations as risk ratios are generated from data derived from typical industrial settings. Such settings do not possess many safeguards present in the rail industry such as fixed guideways, alerters, dead man switches, and computer-controlled yard signals. The risk associated with the typical industrial setting may be slightly greater than what would be expected in the typical commuter rail operations. Therefore, the risk ratios from the FRI that have been derived in these analyses may overestimate the degree of risk associated with a specific schedule due to the assumptions on which the ratio is based. The actual risk in the passenger rail setting may be much less.

In their discussion of the development of the FRI, the authors also note the work of Dembe et al. (2004) who identified a "dose response" relationship between number of hours worked per week and frequency of incidents. Their data suggest the risk of incidents was approximately doubled for individuals who worked 65 hours or more compared to those who worked less than 40 hours per week.Spencer, Robertson, and Folkard, (2006) discussed two issues regarding the limitations of the Dembe findings. First, working longer hours means that a person is highly likely to have a greater exposure to hazardous situations than those working shorter hours. In addition, when the work week is extended beyond about 40 hours, individuals will almost certainly be exposed to longer shifts, longer spans of shifts, and quite probably riskier times of day. It is difficult to separate the effects of longer hours from these other factors.

In fact, Spencer, Robertson, and Folkard, 2006 argue

> Considering the weekly work hours in isolation from other factors is fairly meaningless since, depending on their composition, long weekly work hours can prove less risky than short weekly work hours. Thus, for example, relative to a "standard" work week of 40 hours comprising 5 successive eight hour day shifts, a 40 hour week comprising 5 successive eight hour night shifts is associated with a 34% increased risk while a 60 hour week comprising 5 successive twelve hour day shifts is associated with only a 28% increased risk . Clearly the *length of the working week cannot sensibly be considered in isolation from the precise work schedule.* Likewise limits on the length of the working week are likely to be of little use in restricting risk unless they form part of a more comprehensive set of limits. (pg 39) (Italics added)

Using FRI, the following estimates of risk were generated for several different work schedules. First, a typical eight-hour daylight work schedule is presented in Figure 2.3.

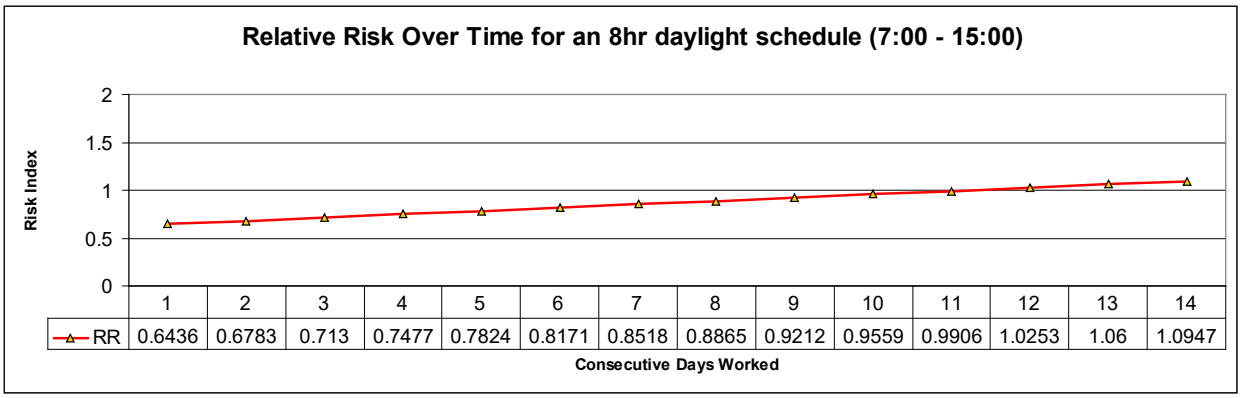

Figure 2.3 Relative risk over 14 days 8-hour schedule

The schedule depicted in Figure 2.3 achieves a relative risk of 1.09 (RR=1.09) at the end of 14 days of consecutive daytime work. Using the assumptions from the formulation of the model, we arrive at a much lower estimate of risk than what is determined simply by extrapolating from the four days of data and the average relative risk ratio derived from that analysis.

Looking at the data for night shifts (23:00 to 07:00) in Figure 2.4 produces a similar graph, with a maximum RR=1.85 at the end of the 14-day period. Remember, this might be over-restrictive due to possible adjustment to nighttime work for some 30% of the workers. Last, examining the relative risk associated with an afternoon shift is shown in Figure 2.5. The relative risk associated with this type of schedule, running from 15:00 to 23:00 or a typical swing shift indicates that there is a steadily increasing level of risk that increases to a RR = 1.635.

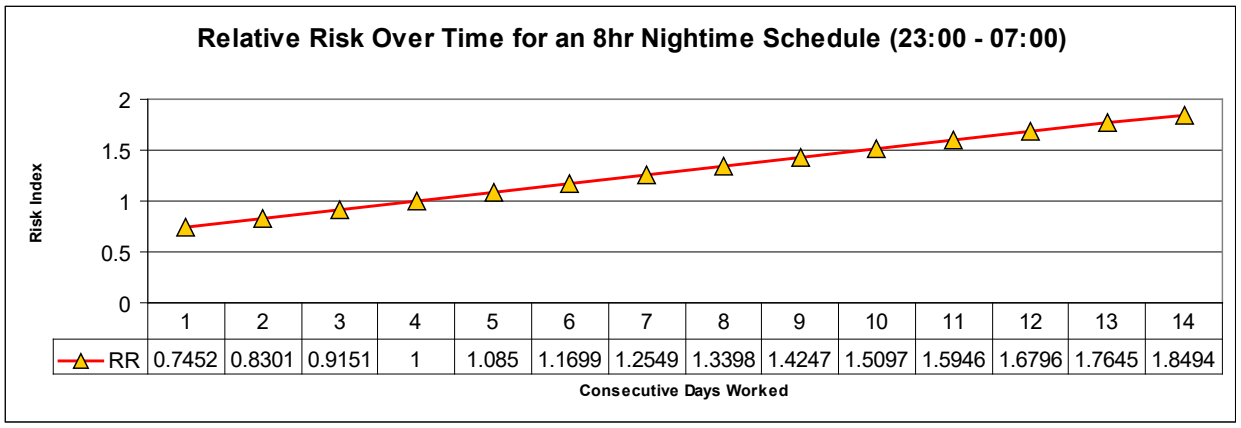

Figure 2.4 Relative risk over 14 days for an 8-hour midnight schedule

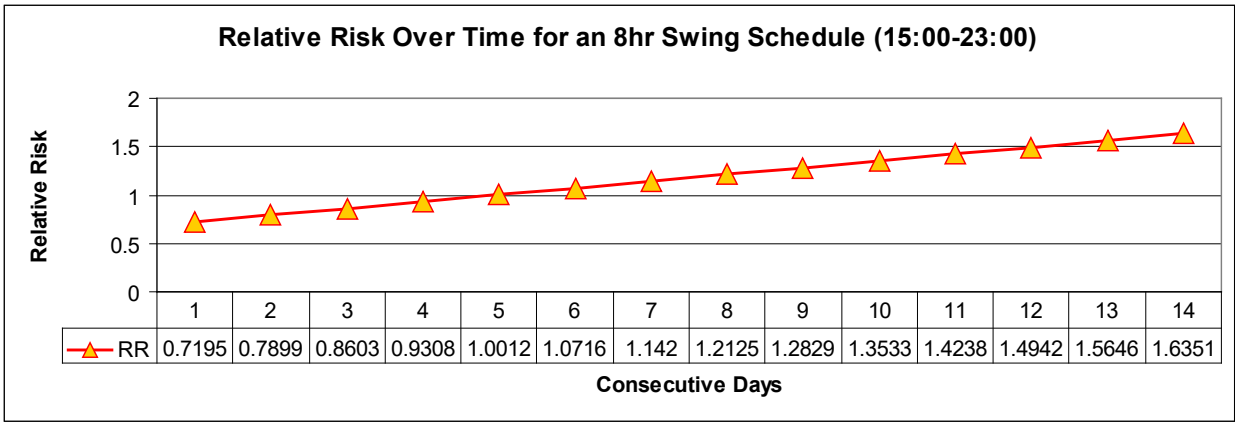

Figure 2.5 Relative risk for 8-hour swing shift over 14 consecutive days

Extending these analyses to 12-hour shifts was also performed. These analyses are not graphed or plotted, but presented in tabular format in the Table 2.1.

Table 2.1 Relative risk of 8-hour and 12-hour schedules over 14 consecutive days

Consecutive Day	07:00-15:00	15:00-23:00	23:00-07:00	07:00-19:00	19:00-07:00
1	0.62	0.69	0.72	0.81	0.92
2	0.65	0.76	0.80	0.85	1.03
3	0.69	0.83	0.88	0.90	1.15
4	0.72	0.90	0.96	0.94	1.26
5	0.75	0.96	1.05	0.98	1.37
6	0.79	1.03	1.13	1.03	1.49
7	0.82	1.10	1.21	1.07	1.60
8	0.86	1.17	1.29	1.11	1.71
9	0.89	1.23	1.37	1.16	1.83
10	0.92	1.30	1.46	1.20	1.94
11	0.96	1.37	1.54	1.25	2.05
12	0.99	1.44	1.62	1.29	2.17
13	1.02	1.51	1.70	1.33	2.28
14	**1.06**	**1.57**	**1.78**	**1.38**	**2.39**

These calculations, generated from the FRI, show that the relative risk associated with these schedules increases as one works more hours and works on schedules that are not standard daylight schedules. The relative risk on the last day of a 14-day 12-hour midnight shift is greater than working a 14-day eight-hour or 12-hour daylight shift (RR = 2.39 vs. 1.06, 1.38). Interestingly, an 8-hour afternoon or swing shift (RR=1.57) appears to have a greater risk than a 12-hour day shift (RR=1.38).

Similar analyses can also be conducted on schedules that have either one or two rest days over a 14-day period. Data in Table 2.2 shows there is little increased risk on the on the 12th or 13th day of either the 5-2 or 6-1 daylight schedules (RR=.77 vs. .85 respectively for a daylight schedule) of a 14-day period. The risk is less than that associated with a standard rotating-shift work schedule, which is normalized at 1.00. Risk increases steadily over the course of the work week and risk associated with nighttime schedules is consistently higher than that of daylight schedules.

Table 2.2 Relative risk of 8-hour and 12-hour 5-on 2-off and 6-on 1-off

Consecutive Day	07:00-15:00	07:00-15:00	15:00-23:00	15:00-23:00	23:00-07:00	23:00-07:00	07:00-19:00	19:00-07:00
	5 on - 2 off	6 on - 1 off	5 on - 2 off	6 on - 1 off	5 on - 2 off	6 on - 1 off	5 on - 2 off	6 on - 1 off
1	0.62	0.62	0.69	0.69	0.72	0.72	0.81	0.81
2	0.65	0.65	0.76	0.76	0.80	0.80	0.85	0.85
3	0.69	0.69	0.83	0.83	0.88	0.88	0.90	0.90
4	0.72	0.72	0.90	0.90	0.96	0.96	0.94	0.94
5	0.75	0.75	0.96	0.96	1.05	1.05	0.98	0.98
6		0.79		1.03		1.13		1.03
7								
8	0.64	0.68	0.72	0.81	0.83	1.13	0.83	0.89
9	0.67	0.71	0.79	0.88	0.91	1.21	0.87	0.93
10	0.70	0.75	0.86	0.95	0.99	1.29	0.92	0.97
11	0.74	0.78	0.93	1.01	1.07	1.37	0.96	1.02
12	0.77	0.81	0.99	1.08	1.15	1.46	1.00	1.06
13		0.85		1.15		1.54		1.10
14								

2.2 Fatigue Risk Associated with Work Schedules

In summary, depending on assumptions about the underlying nature of the shape of data distribution, the fatigue and accident risk extrapolated from the four days of data reported by Folkard will have different values. These assumptions influence the discussion of how many consecutive days a person should work. The present discussion and additional analyses suggest that consecutive work days may have some relative risk of greater accidents, but that factors such as start times, work breaks, and other safeguards and mitigations may mitigate those risks. The present study will investigate and examine the use of various fatigue countermeasures in an attempt to reduce risk.

Previous research has found a linear model to be a reasonable fit and a parsimonious approximation to progression of relative risk ratios over time. Additional research is needed to verify true nature of the data. Results of analyses of 5-2 and 6-1 daytime work schedules show low overall risk (RR<1.00) and little difference between the two. Comparisons of the relative risk associated with 5-2 and 6-1 nighttime schedules show that relative risk is greater than one (RR = 1.15 vs. 1.54) on the 12th and 13th day of a 14-day period. Caution should be used when simply counting the number of days worked or the number of hours worked as they do not necessarily relate to increased risk for incidents as shown by the fact that certain five-day schedules are riskier than four-day schedules.

2.3 Railroad Sleep Patterns

In 2009, the FRA published a study of the work/rest schedules and sleep patterns of U.S. railroad train, engine, and yard personnel. The FRA conducted a survey of a random sample of railroad employees to obtain information needed to develop work rest guidelines for the hours of service. At that time, it was estimated that there were 85,594 (FRA, 2009, pg. 14) railroad employees in the train yard and engine service. To obtain a sufficiently large sample of employees for the study, a statistical technique was employed to generate the number of surveys needed for analysis to calculate an appropriate power.

The FRA estimated that a sample size of 340 would be needed to achieve its target of trying to estimate the amount of sleep obtained by TYE crews. This estimate was developed using a standard formula. In addition, given that only a 42% response rate could be expected, the FRA planned to oversample the TYE employees and send out 809 (=340/.42) surveys.

3. RESEARCH OBJECTIVES

An examination of work schedule data from the Short line railroad industry including hours of sleep and hours of work will be made. The objectives of this project are as follows

1. Identification and assessment of typical short line railroad work schedules
2. Identification of fatigue risks associated with schedules worked during peak hours
3. Identification of work schedule modifications that may lead to reduced fatigue
4. Identification of work schedules adjusted with the inclusion of fatigue countermeasures or interventions likely to lead to a reduced level of fatigue risk
5. Recommendations for best practices to implement findings

4. METHODOLOGY

4.1 Participants

A sample of participants from the Short line railroad workforce was drawn from the ranks of existing Short line railroad employees to complete surveys, sleep logs, and focus groups to assess their current levels of fatigue and alertness.

4.2 Sampling Plan and Sample Size

The sampling plan used a selection of train and engine service workers in proportion to the participating railroads and various carriers who volunteer to participate in the study from around the country. Based on our initial power analyses, a sufficiently large sample to permit comparisons was planned. The sampling plan adopted was designed to sample from the four main regions of the country: north, south, east, and west. Also, it was designed to ensure that there would be a sufficient number of day versus night shift employees to permit good comparisons. Finally, it was planned that a sufficient number of railroad employees would be recruited to permit paired comparisons of fatigue levels following institution of the fatigue counter measures.

To permit the comparison between existing data and current operational conditions, several comparisons were planned. First, analyses were conducted to compare Short line data to previously published data for Class I's. Analyses were conducted with the goal of achieving a power of .90 for a medium effect size (d=.50) and an alpha level of .05. Results indicated that to compare observations and statistics to the previously published FRA report (Gertler & DiiFiore, 2009) based on a sample of 250 railroad employees, that a Short line sample of approximately N=278 would be needed to detect a small effect size.

A second set of analyses designed to determine the sample size needed to compare the effects of adjusted work schedules and implementation of counter measures in an operational setting was conducted. A baseline sample of self-report measures and sleep logs was gathered and compared to a matched sample after a sufficient amount of time following counter measures implementation. Such a design had the goal of achieving a power of .90 for a medium effect size (d=.50) and an alpha level of .05. A total sample size with 70 participants in each group was selected for a two-group independent sample and matched pair sample of 37. The sample needed to compare two independent groups with a smaller effect size (d=.30) at a power of .90 would be 278 or 139 in each group.

Table 4.1 Comparison of samples needed

	Two Group Independent Sample		Matched Pairs	
	d=.30 B=.90	d=.50 B=.90	d=.30 B=.90	d=.50 B=.90
Sample	278	140	37	36

4.3 Instruments

The instruments that will be used to assess the degree of fatigue and alertness for the desire comparisons will be standard measures that have been used in previous studies. The surveys are described in Gertler and DiFiore (2009). Additional measures included in the survey have also been used in previous studies and included the Epworth Sleepiness Scale, the Pittsburgh Sleep Quality Index and additional background questions. The Denver Sleep Diary was also administered (Sherry, 2005).

5. RESULTS AND ANALYSIS

5.1 Descriptive Statistics

Data were gathered according to the sample plan recommendations. Data were obtained from railroads in various regions of the country (see Figure 5.1). This is a representative sample of the membership of the ASLRRA. Based on data collected usable data from 151 individuals were obtained. The start and end times tables below indicate that approximately 27.4% (37/135) work shifts began between 11 p.m. and 6 a.m. This would be consistent with the group size needed for a paired means comparison of 37 study participants as noted above (Power =.90, alpha =.05, and effect size = .50).

The demographic characteristics of the sample reveal that the sample is predominantly white, with a high school education and an average age of 41 years. This number is slightly below the 156 for within group (pre-post comparisons) that were originally targeted in the sampling plan.

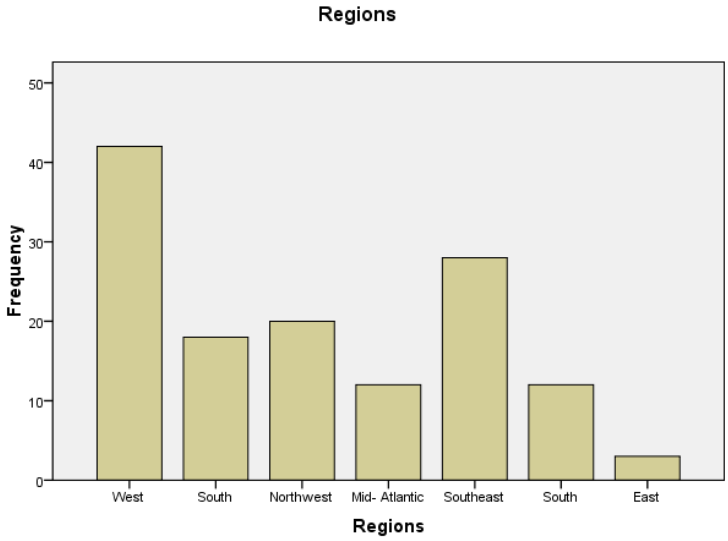

Figure 5.1 Respondents by region

5.2 Start Times and Shifts

To address the issues of fatigue, we must also examine the times that people were working. The following charts (Figure 5.2) show the reported start times and type of shift that persons in the sample were working.

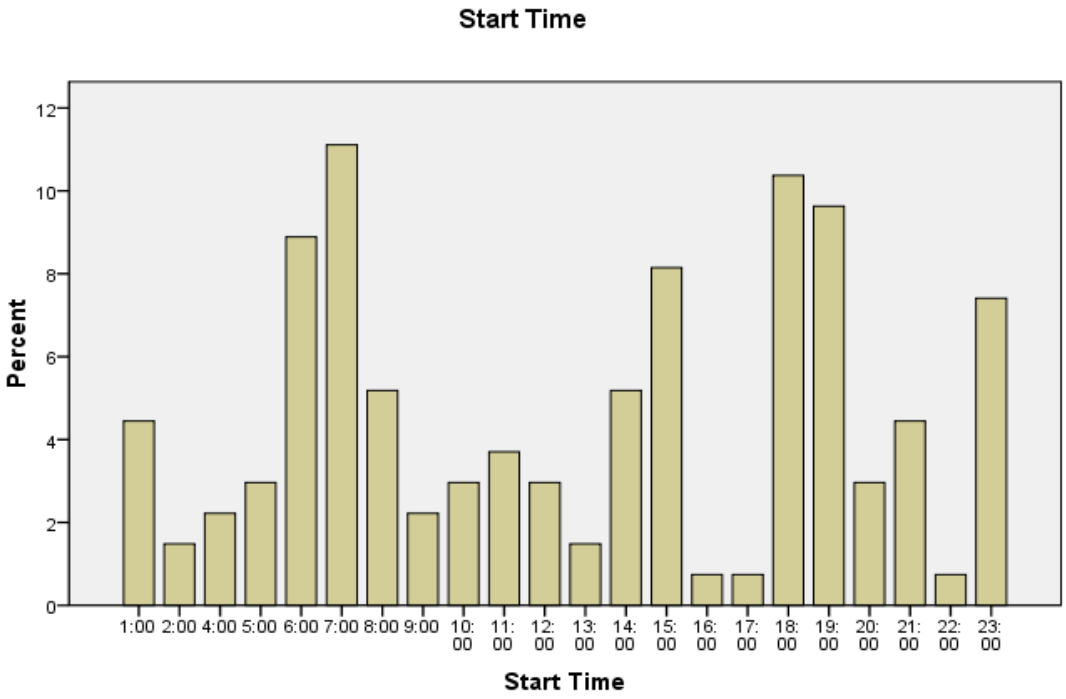

Figure 5.2 Percent of respondents start work at various times

The start times were used to designate the type of shift. Approximately equal numbers of persons in the day and afternoon shift and about half as many working midnight shifts (Day = 54, Afternoon = 49 and Night = 32).

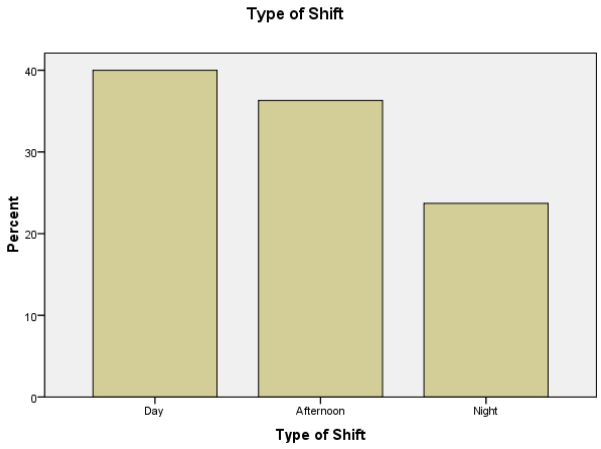

Figure 5.3 Percent respondents at various types of shifts

The average number of hours of sleep obtained per 24-hour period was determined. The following chart (Figure 5.4) shows that the average hours of sleep per night reported by our sample was approximately 5.9 hours.

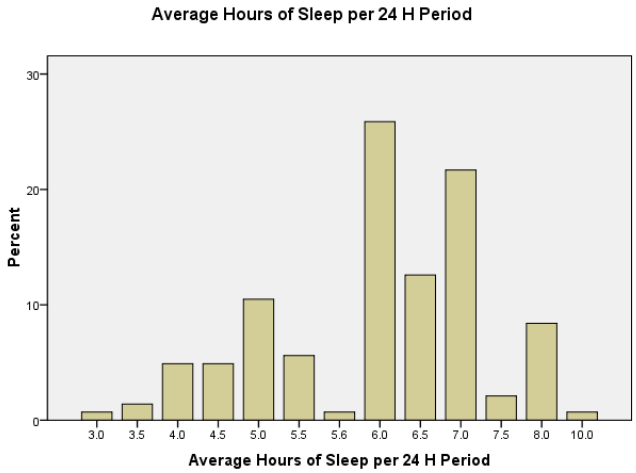

Figure 5.4 Average Hours of Sleep Obtained

Please note that while there were 151 total useable surveys not all surveys had complete data. Consequently, the number for various measures varies from 112 to 135. As can be seen in Table 5.1, the average number of hours of sleep obtained by persons on the different shifts varies from 5.87 for those on the afternoon shift to 6.45 for those on the day shift.

Table 5.1 Average hours of sleep per 24-hour period

Type of Shift	Mean	N	Std. Deviation
Day	6.452	51	.8718
Afternoon	5.872	47	1.2873
Night	6.000	27	1.2403
Total	6.137	125	1.1469

Thus, there is an almost equal distribution of start times across the clock in the sample we have gathered. This is not reflective of the actual situation in the short-line workplace, where only a small percentage of individuals actually work nights.

Having determined the start-times, it was also deemed useful to assess how much sleep was associated with each of the start times. As can be seen in the following chart (Figure 5.5), the lowest amounts of sleep were obtained by people who started work at 1 a.m. Data would probably have been a little less favorable if findings for the 2 a.m. start had been produced by more than two subjects. This average of seven hours seems high and was probably due to the fact that both people who had these jobs started regularly at 2 a.m. and only worked for six hours. Thus, they had plenty of time to recover.

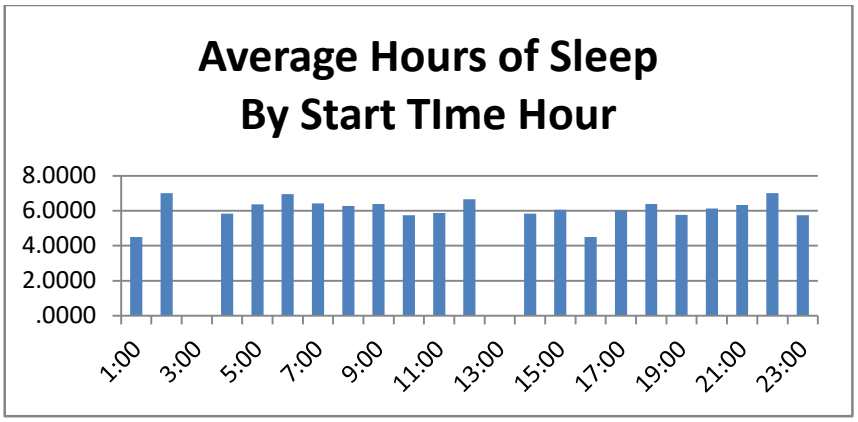

Figure 5.5 Average hours of sleep by start hour

Similarly, only a small portion of the work force actually end their work shift after midnight and before 5 a.m. (See Figure 5.6) This percent totals about 21.9% who state that their end time is 5 a.m. or before. Consequently, we can conclude that only a small portion, or about 20% of people were working into the high risk for fatigue zone.

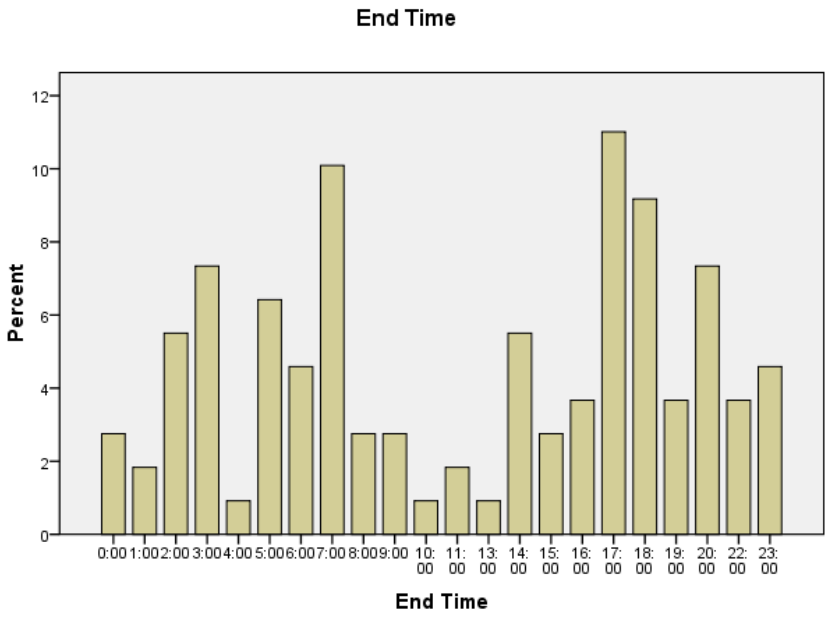

Figure 5.6 Work end times by hour of day

It could be argued that only about 22% of the workforce is engaged in work that takes them into the most serious times for being at risk for fatigue.

5.3 Fatigue Measures

In addition to hours of sleep obtained for the various schedules, results were also obtained for the Epworth Sleepiness Scale (ESS). The ESS is designed to indicate to what extent a person feels abnormally tired based on a series of questions. The scale has been used in other studies with railroad personnel.

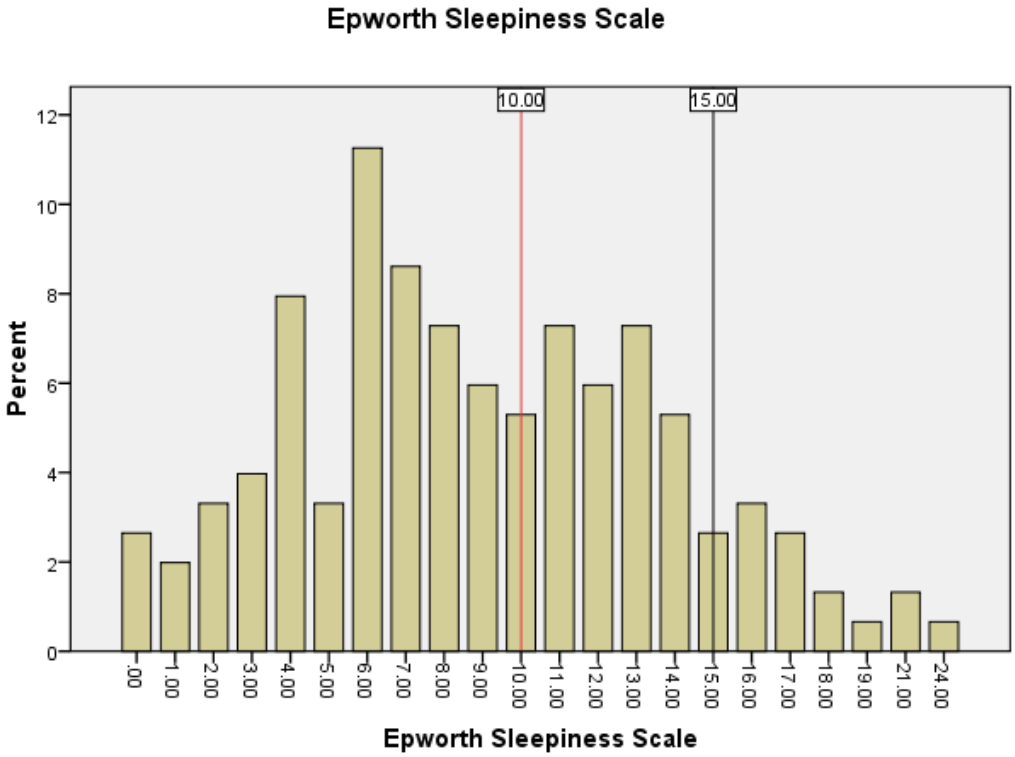

Figure 5.7 Epworth Sleepiness Scale scores by hour of day

The mean of the Epworth scale was 9.0 with a standard deviation of 4.8. Previous research has established 10.0 as the cutoff between normal levels of sleepiness and borderline cases. The clinical cutoff is thought to be 15 or above.

As can be seen from Figure 5.7, approximately 56.3% of the total number of respondents are below the cutoff. Additionally, a total of 12.5% of respondents are at or above the clinical cut off score of 15.

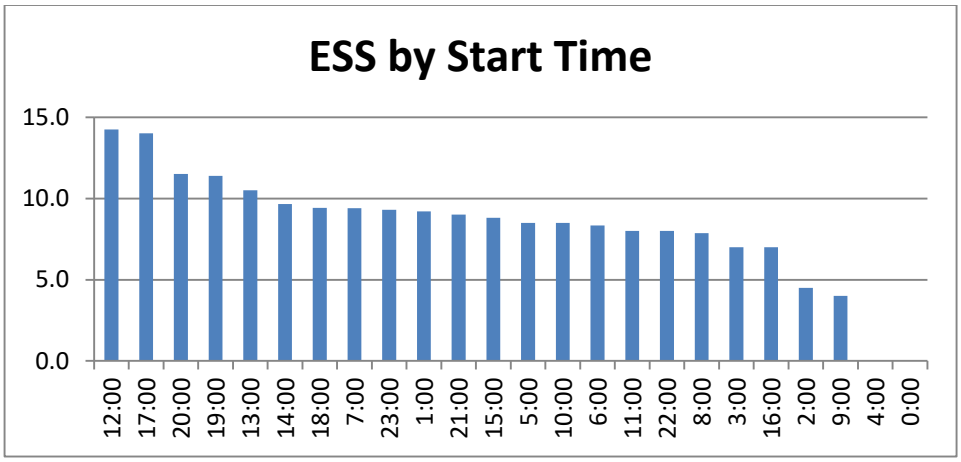

Figure 5.8 ESS by start time

Data reveal an interesting finding when the Epworth scores are plotted against the start time hour. Epworth scores are higher for those who start work in the late afternoon and early evening. Apparently, the fatigue levels of people working the midnight hours are not as pronounced as those from other shifts. Perhaps they have learned to adapt to the demanding conditions of these work schedules.

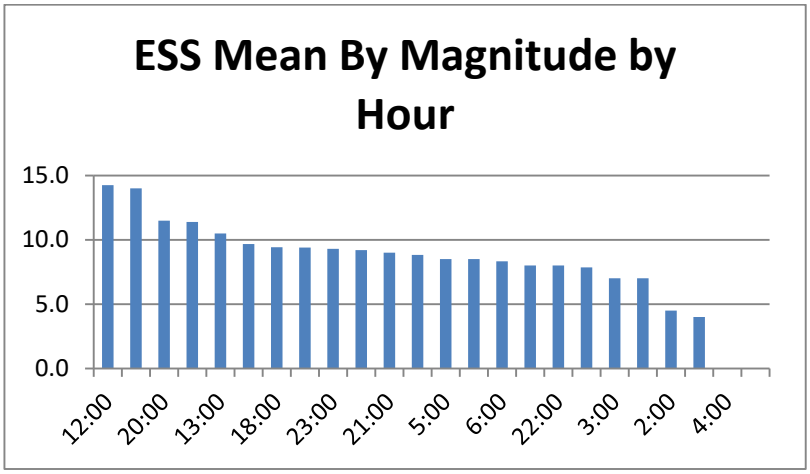

Figure 5.9 ESS by magnitude and start hour

5.4 Evaluation of Fatigue Countermeasures

5.4.1 Sleep Logs and Fatigue Modeling

The FRA has identified the use of sleep logs or sleep diaries as one of the main techniques for gathering information on railroad employees work habits. Completion of Sleep Logs requires the individual to record their work start and end time and their sleep start and end time. Such a technique is useful for individuals working variable schedule jobs frequently found in the railroad. Data are coded, transcribed, and entered into typical modeling software such as FAID or FAST to determine the average effectiveness or fatigue levels. Individuals who are below the predetermined fatigue cutoff level of 70 more than 20% of the time are deemed to be at a significant risk for fatigue. Similarly, their work schedule is also deemed to be at-risk.

In the present study, participants completed the self-report questionnaires and were also asked to complete sleep logs. Forty-three individuals agreed to participate in the study and complete a pre- and post-sleep log or sleep diaries following the implementation of fatigue counter measures subsequent to schedule changes. These sleep logs provided data presented in Table 5.2. The majority of the sleep logs (57%) were from individuals working predominantly night shifts (25/43) that typically began at 18:00 hours and progressed until 6:00 hours the next day. Combined, 61% of the sleep logs were from individuals working predominantly both night and variable shift schedules (27/43).

Sleep logs were coded and 21-day schedules were entered into standard modeling software (FAST). Results of the analysis produced the plotted results in the appendices. Data in Table 5.2 also indicate the average number of hours worked, average effectiveness score and also the average percentage of time that workers fall below the cutoff levels. These schedules provide data to examine the effectiveness of the fatigue counter measures being evaluated.

5.5 Results of Analysis of the Fatigue Countermeasures

The following analyses, based on data collected from the study, participants completion of Sleep Diaries, describes the existing work schedules, level of fatigue and accident risk associated with schedules, and effects of countermeasures on the reduction of fatigue risk in work schedules. The analyses will present a typical schedule, a night schedule and a variable work schedule. Effects of countermeasures interventions will be modeled to demonstrate reduction of fatigue risk following the use of fatigue countermeasures.

Evaluation results of the fatigue countermeasures demonstrated that use of naps during the work period would result in a significant reduction in fatigue such that estimates of overall fatigue fall within the accepted and recommended fatigue risk levels. As can be seen in the appendices, specifically schedule “CP-002 – Actual” the fatigue mitigation counter measures modeled in the plots suggest that with the implementation of 60 or 90-minute naps significant reductions in fatigue could occur. The proposed countermeasures would be effective in managing the negative effects of fatigue.

Table 5.2 Sleep log data by type of shift

#	Shift Type	Avg Start Time	Hrs Wrkd	Avg Eff	% BCL
3	Afternoon	15:00	9.13	95.60	2.78
6	Afternoon	15:00	10.93	95.70	0.01
7	Afternoon	15:00	9.27	96.50	-
8	Afternoon	15:00	9.46	95.04	1.22
10	Afternoon	13:00	8.50	80.15	39.77
12	Afternoon	21:00	11.41	98.69	-
13	Afternoon	16:00	9.78	82.74	28.18
14	Afternoon	15:00	11.00	93.59	7.33
20	Afternoon	15:00	10.00	90.40	2.35
27	Afternoon	15:00	8.95	93.03	0.32
11	Day	7:00	8.93	89.46	14.80
19	Day	7:00	13.63	97.95	-
24	Day	6:00	11.95	91.15	0.76
29	Day	7:00	9.67	89.68	9.48
30	Day	7:00	8.11	96.52	-
34	Day	6:00	9.54	91.44	-
44	Day	7:00	9.57	91.32	4.10
1	Night	3:00	12.27	85.02	1.78
2	Night	22:00	9.95	80.44	35.87
4	Night	21:00	7.22	85.43	27.24
5	Night	22:00	4.88	80.02	40.62
9	Night	19:00	10.00	81.77	39.85
15	Night	22:00	9.27	88.96	21.00
16	Night	21:00	7.93	93.84	6.13
17	Night	18:00	11.24	76.11	50.60
18	Night	18:00	10.13	83.77	38.40
21	Night	18:00	12.92	90.47	7.95
22	Night	20:00	13.39	74.89	57.07
23	Night	19:00	10.05	90.20	9.90
25	Night	20:00	12.70	74.63	42.62
26	Night	19:00	8.43	87.85	7.14
31	Night	18:00	11.90	93.13	2.30
33	Night	22:00	11.29	57.03	99.42
35	Night	19:00	9.08	90.74	10.66
36	Night	18:00	11.36	89.20	7.72
37	Night	17:00	12.06	88.10	14.20
38	Night	17:00	9.77	90.77	10.73
39	Night	1:00	12.25	74.14	78.46
40	Night	16:00	11.07	92.71	5.40
41	Night	21:00	8.45	90.37	17.49
42	Night	22:00	10.09	97.27	1.95
43	Night	23:00	7.16	74.13	56.55
28	Variable	5:00	8.09	85.71	18.15
32	Variable	22:00	10.62	80.65	33.96

The most accepted method of evaluating changes is use of the SAFTE model endorsed by the FRA. (Hursh, et al. 2006). Applying the SAFTE model to the work schedules obtained from the carriers in the Short line industry will provide a reasonable sample against which to evaluate countermeasures.

The SAFTE Model has been described in some detail by the authors as a "three-process quantitative model" (pg. a44) (Hursh, Et. al., 2004). The model was developed for use with military personnel to estimate performance in the military field setting. The most recent version of the model was developed based on data obtained from the Sleep Dose Response Study (Balkin, et. al., 2000), which has also been used in construction of the Fatigue Avoidance Scheduling Tool (FAST) (Eddy and Hursh, 2001). The model is conceptualized as a sleep reservoir that influences process, which influences the capacity of an individual to perform cognitive processes and complete tasks. With each unit of time that a person is awake, the contents and capacity of the sleep reservoir is decreased. The reservoir is restored in accordance with the intensity and quality of sleep obtained over time. Sleep intensity is directly affected by the time of day and sleep quality is affected by various real-world demands. The model output, level of effectiveness, is modulated by the circadian effects of time of day, and the depletion or accumulation of the sleep reservoir. Thus, the SAFTE model is similar to one that was suggested by Folkard and Akersted (1987).

The Hursh, et al (2006) report indicates that that the there is a reliable relationship between reduced effectiveness and an increased risk of human factors accidents. Below an effectiveness level of 70, the risk of human factors accidents is increased by about 20 percent; below an effectiveness level of 50, it is elevated by 65 percent. Using effectiveness measures, it is possible to develop an estimate of the relative risk of an accident due to fatigue. For example, if a person gets less than eight hours sleep on a regular basis, then effectiveness at 0400 hr (the circadian minimum) will be below a score of 70 and accident risk will be elevated by at least 21 percent. If the person gets less than four hours sleep, then effectiveness at 0400 hours is below a score of 65 in one day, less than a score of 60 in two days, and less than a score of 50 in seven days, at which point accident risk is elevated by 65 percent. After seven days of 4 hours sleep per day, effectiveness at the circadian peak (about 1600 hours) is nearing a score of 70 or an elevated risk of 14-21 percent in the day time.

Thus, using the FAST tool to model various changes to work schedules can be an effective method for evaluating the effectiveness of fatigue countermeasures in the real world. The FAST tool, based on the SAFTE permits the introduction of various changes into work schedules to examine the impact of the alterations on the overall effectiveness scores.

The work schedules obtained from the Short line railroad industry study participants provide a representative sampling of work schedules. Accordingly, representative schedules can be modified with the introduction of fatigue countermeasures and examined for the level of fatigue risk that they present. Also the representative schedules can be studied to determine how introduction of countermeasures would impact the level of fatigue effectiveness.

The following graphs (also shown in the appendices) provide an evaluation of the fatigue countermeasures. Typical work schedules and those with risk fatigue are presented. Schedules that were predominantly night jobs were modeled and then revised with napping countermeasures included. Additional supporting data show the modeled schedules for additional participants in the study.

5.6 Typical Schedule

Table 5.3 Schedule: JB-001 − actual

	Start			End			Stats		
	Day	Date	Time	Day	Date	Time	Dur	Eff	%BCL
1	Sun	3/18/2012	14:00	Sun	3/18/2012	20:00	360	94.86	0.00
2	Mon	3/19/2012	12:00	Mon	3/19/2012	23:59	719	89.62	0.00
3	Tue	3/20/2012	12:00	Wed	3/21/2012	01:00	780	90.86	0.00
4	Wed	3/21/2012	13:00	Thu	3/22/2012	00:00	660	88.75	0.00
5	Thu	3/22/2012	12:00	Fri	3/23/2012	00:00	720	89.70	0.00
1	Sun	3/25/2012	14:00	Sun	3/25/2012	20:00	360	97.48	0.00
2	Wed	3/28/2012	13:00	Thu	3/29/2012	00:00	660	95.98	0.00
3	Thu	3/29/2012	12:00	Fri	3/30/2012	01:00	780	93.28	0.00
1	Sun	4/1/2012	14:00	Sun	4/1/2012	21:00	420	91.57	0.00
2	Mon	4/2/2012	12:00	Tue	4/3/2012	00:00	720	88.82	0.00
3	Tue	4/3/2012	12:00	Wed	4/4/2012	00:00	720	89.65	0.00
4	Wed	4/4/2012	13:00	Thu	4/5/2012	00:00	660	89.11	0.00
5	Thu	4/5/2012	12:00	Fri	4/6/2012	02:00	840	90.28	0.00
1	Mon	4/9/2012	12:00	Tue	4/10/2012	01:00	780	92.22	0.00
2	Tue	4/10/2012	12:00	Wed	4/11/2012	00:00	720	96.70	0.00
							659.93	91.62	0.00

The following graph, Figure 5.10, reflects the work schedule of the study participant JB-001. The green area at the top of the graph demarcates the optimal range of effectiveness for performing various duties with the least likelihood of a human factors caused accident or incident occurring. The yellow region demarcates a cautionary range and the pink area, or red zone, indicates a high probability of a fatigue risk and a higher probability of a human factors-caused accident.

The waking activity of the study participant is reflected in the line drawn under each date column. The line covers the 24-hour period of each calendar date. The bolded darker portion of the graphed line is the work period, while the lighter portion reflects the non- work activity portion of the day. Along the bottom, the total work period is demarcated by a red block and the sleeping period is indicated with a blue block. Effectiveness scores range from 0 to 100. The FRA recommends an effectiveness score above 70. The trailing line on the far right indicates that no data was collected. No work schedule was provided and therefore, no fatigue analyses conducted. The small text box inset on the graph indicates an event or an observation taken on March 26, 2012 at 15:16 p.m. where the participant's effectiveness score was 96 to 95 with a 15% confidence interval at that point in time. On the far right axis, an estimate of the participant's cognitive performance with a blood alcohol level of above or below .05 is provided. This is a controversial scale based on hypothesized estimates and correlations with other published data. It should not be confused with actual alcohol consumption or performance.

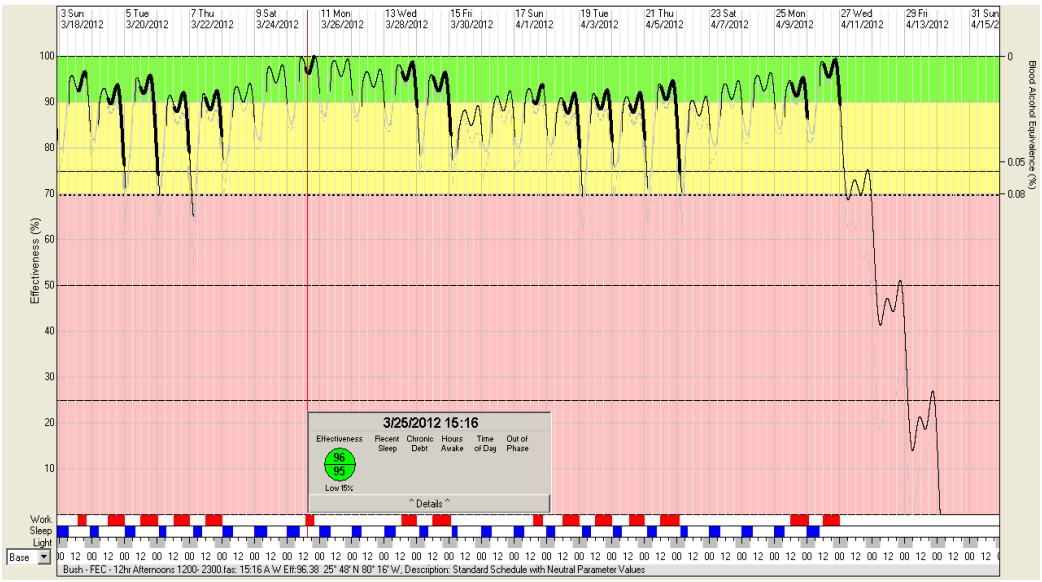

Figure 5.10 Schedule: JB-001 - actual

Results of this schedule's analysis show a typical day job with no fatigue risk problems—the individual never falls below the cutoff of 70. The individual worked an average of 659 minutes per day with an average effectiveness score of 91.62 and with an average of 0% of the time below cutoff levels. Consequently, no fatigue countermeasures are needed.

5.7 Night Schedule

As noted above, about 15% of the work schedules from the Short Line Association involve work conducted during the midnight hours between 12 midnight and 6 a.m. These work schedules have a higher risk, as can be seen in Table 5.4 and Figure 5.11.

Table 5.4 Schedule: JB-001 − actual

J0012 - Edited								
Start			End			Stats		
Day	Date	Time	Day	Date	Time	Dur	Eff	%BCL
Tue	7/10/2012+	01:00+	Tue+	7/10/2012+	09:00+	480	72.42	82.5
Tue	7/10/2012+	20:00+	Wed+	7/11/2012+	10:00+	840	77.20	54.29
Wed	7/11/2012+	21:00+	Thu+	7/12/2012+	08:00+	660	77.79	47.73
Thu	7/12/2012+	20:00+	Fri+	7/13/2012+	09:00+	780	79.04	44.23
Fri	7/13/2012+	20:00+	Sat+	7/14/2012+	10:00+	840	79.06	45.00
Mon	7/16/2012+	20:00+	Tue+	7/17/2012+	11:00+	900	88.20	33.67
Wed	7/18/2012+	01:00+	Wed+	7/18/2012+	11:00+	600	78.59	56.17
Wed	7/18/2012+	21:00+	Thu+	7/19/2012+	10:00+	780	84.29	35.9
Thu	7/19/2012+	21:00+	Fri+	7/20/2012+	09:00+	720	82.76	33.75
Fri	7/20/2012+	23:00+	Sat+	7/21/2012+	10:00+	660	80.58	41.82
Mon	7/23/2012+	20:00+	Tue+	7/24/2012+	10:00+	840	85.90	28.33
Tue	7/24/2012+	20:00+	Wed+	7/25/2012+	09:00+	780	85.14	25.00
Wed	7/25/2012+	20:00+	Thu+	7/26/2012+	10:00+	840	82.56	30.00
Thu	7/26/2012+	21:00+	Fri+	7/27/2012+	12:00+	900	78.88	40.11
Fri	7/27/2012+	22:00+	Sat+	7/28/2012+	12:00+	840	78.20	41.31
Mon	7/30/2012+	21:00+	Tue+	7/31/2012+	10:00+	780	81.26	32.56
Tue	7/31/2012+	21:00+	Wed+	8/1/2012+	09:00+	720	86.06	20.00
Wed	8/1/2012+	20:00+	Thu+	8/2/2012+	09:00+	780	88.00	13.33
Thu	8/2/2012+	20:00+	Fri+	8/3/2012+	09:00+	780	87.38	12.18
Sun	8/5/2012+	21:00+	Mon+	8/6/2012+	09:00+	720	84.69	19.44
						762	82.14	35.82

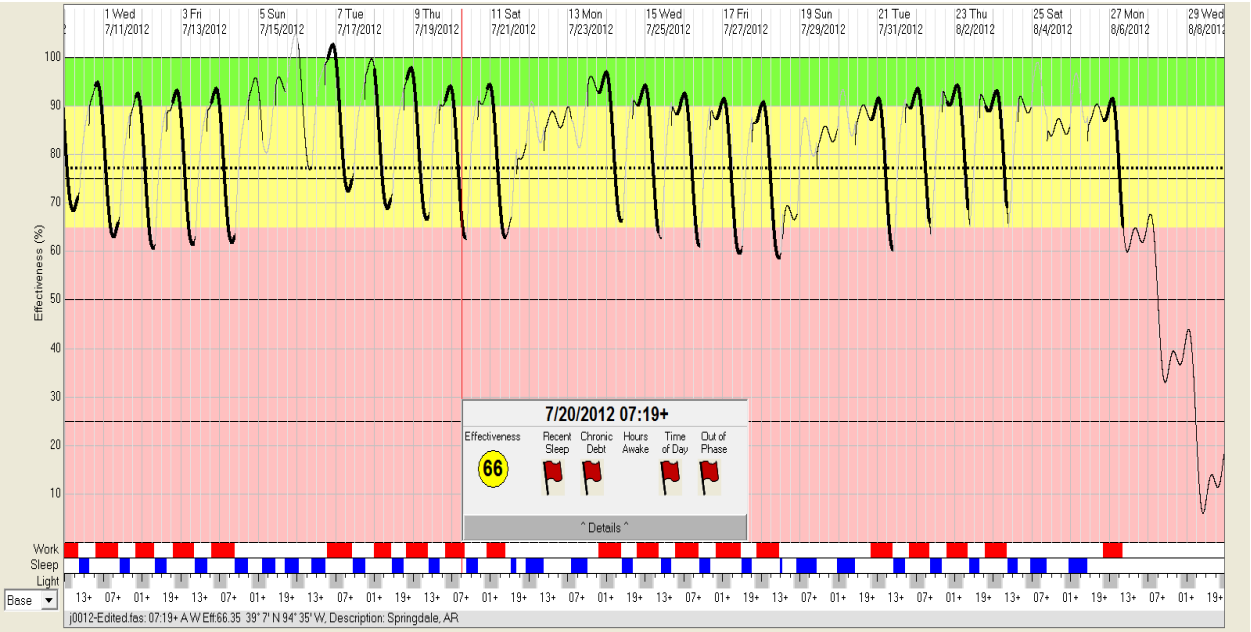

Figure 5.11 Schedule: JB-0012 – actual schedule edited to include days off

This is a typical night schedule that starts at 8 or 9 p.m. and on a regular basis going until 9 a.m. or 8 a.m. the following morning. As seen in the table, average effective ness scores are typically below the expected cutoff line for a significant portion of time. The FRA would consider these schedules to be in the high-risk range for fatigue and possible accidents. Note that the individual displayed does have days off and the amount of sleep obtained on the days off mitigate the amount of time below critical level. Amount of time slept in off periods has an effect on alertness and fatigue during the subsequent work period.

5.8 Evaluation of Napping

The following analyses reflect an introduction of the strategic naps during work hours for the individual working nights. Table 5.5 shows that the introduction of 60-minute naps, during the work period after midnight, mitigates magnitude of the effectiveness scores. Note also that for the graphic displayed in Figure 5.12, the naps are only introduced during the second, but not the third week of work, to demonstrate differences between the use, or lack of, napping. Note also that average effectiveness scores for the time periods following the introduction of naps do not fall below the critical level of 70 and that this is an acceptable level of fatigue. Once the naps are removed however, effectiveness returns to problematic levels.

Table 5.5 J0012 – Actual (Night) – Edited – Plus Naps

Study participant J0012-Edited-Plus 60 M Naps								
Start			End			Stats		
Day	Date	Time	Day	Date	Time	Dur	Eff	%BCL
Tue	7/10/2012+	01:00+	Tue+	7/10/2012+	09:00+	480	72.42	82.5
Tue	7/10/2012+	20:00+	Wed+	7/11/2012+	10:00+	840	77.2	54.29
Wed	7/11/2012+	21:00+	Thu+	7/12/2012+	08:00+	660	77.79	47.73
Thu	7/12/2012+	20:00+	Fri+	7/13/2012+	09:00+	780	79.04	44.23
Fri	7/13/2012+	20:00+	Sat+	7/14/2012+	10:00+	840	79.06	45
Mon	7/16/2012+	20:00+	Tue+	7/17/2012+	11:00+	900	89.42	17.89
Wed	7/18/2012+	01:00+	Wed+	7/18/2012+	11:00+	600	82.11	50
Wed	7/18/2012+	21:00+	Thu+	7/19/2012+	10:00+	780	87.22	29.62
Thu	7/19/2012+	21:00+	Fri+	7/20/2012+	09:00+	720	85.05	32.22
Fri	7/20/2012+	23:00+	Sat+	7/21/2012+	10:00+	660	82.97	48.18
Mon	7/23/2012+	20:00+	Tue+	7/24/2012+	10:00+	840	86.77	34.88
Tue	7/24/2012+	20:00+	Wed+	7/25/2012+	09:00+	780	84.39	34.1
Wed	7/25/2012+	20:00+	Thu+	7/26/2012+	10:00+	840	80.93	40.12
Thu	7/26/2012+	21:00+	Fri+	7/27/2012+	12:00+	900	76.65	50.78
Fri	7/27/2012+	22:00+	Sat+	7/28/2012+	12:00+	840	75.45	52.86
Mon	7/30/2012+	21:00+	Tue+	7/31/2012+	10:00+	780	82.09	38.21
Tue	7/31/2012+	21:00+	Wed+	8/1/2012+	09:00+	720	84.83	29.17
Wed	8/1/2012+	20:00+	Thu+	8/2/2012+	09:00+	780	85.96	23.59
Thu	8/2/2012+	20:00+	Fri+	8/3/2012+	09:00+	780	84.62	23.72
Sun	8/5/2012+	21:00+	Mon+	8/6/2012+	09:00+	720	85.55	24.58
						762	82.12	39.26

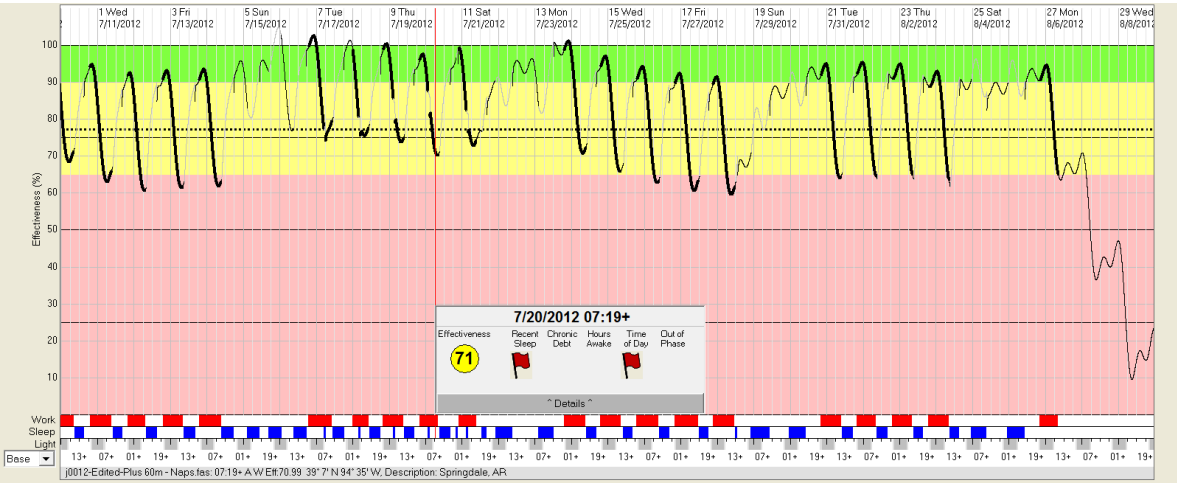

Figure 5.12 Schedule: J0012 – actual schedule edited − off days plus 60-minute naps

The naps are easily seen in the second week of work by gaps in the dark curve during the middle of the shift. They are also shown by the thin perpendicular blue lines on the x axis at the bottom of the graph. The participant's lowest effectiveness score during the week with naps is 71.

In Figure 5.13, the expansion of the napping period to 90 minutes has an even more pronounced impact on the effectiveness scores. Such a countermeasure might not be feasible operationally, however, if circumstances permit, such an approach would reduce fatigue risk. Note that the reduction would produce effectiveness scores highly similar to working days.

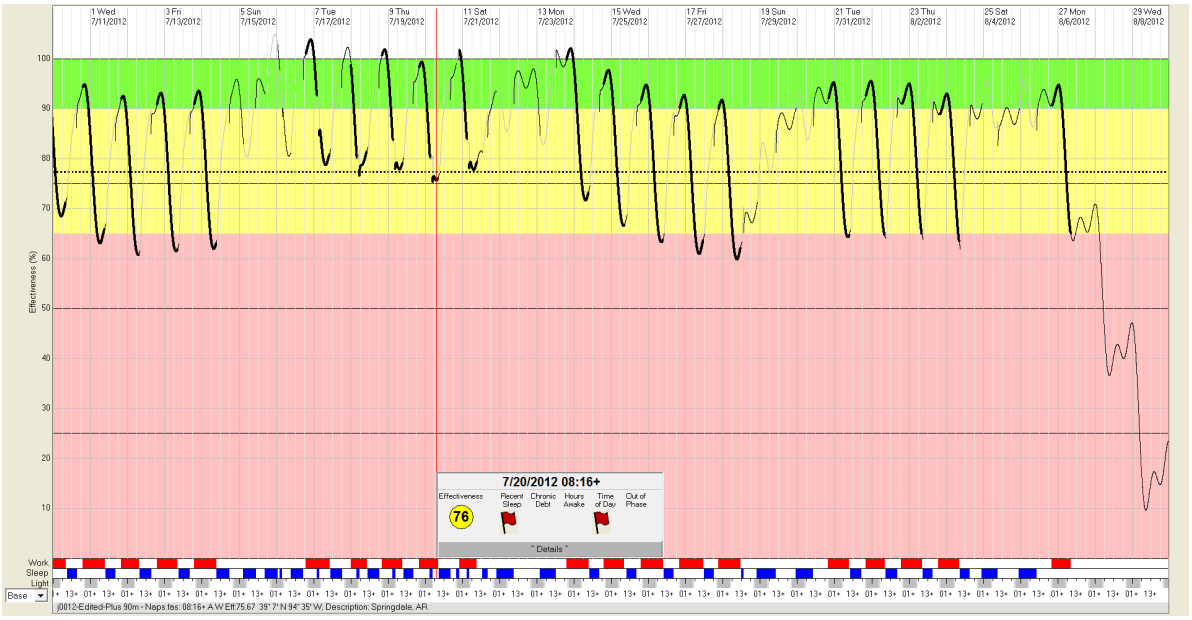

Figure 5.13 Schedule: J0012 – actual schedule edited − off days plus 90-minute naps

In addition to the schedules submitted by the study participants displayed in the appendices, several different typical work schedules used by members of the Short Line Association were subjected to modeling. For example, one work schedule depicted in Figure 5.14 through 5.17 was studied. First, by adding an hour to each sleep period, overall average effectiveness increased thereby decreasing the risk of fatigue (see Figure 5.15 and 5.16). Next, by adding an operational nap period of 60 minutes, risk of fatigue was further reduced (See Figure 5.17).

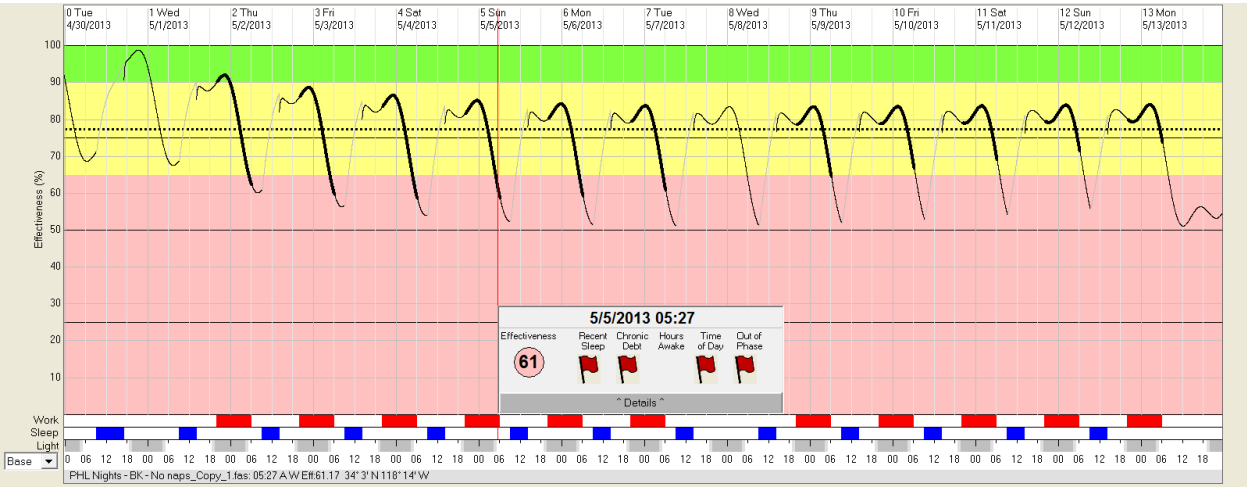

Figure 5.14 Schedule: PHL-BK _Nights - 2000 - 0600 – (10 hrs work) (5 hrs sleep) no naps

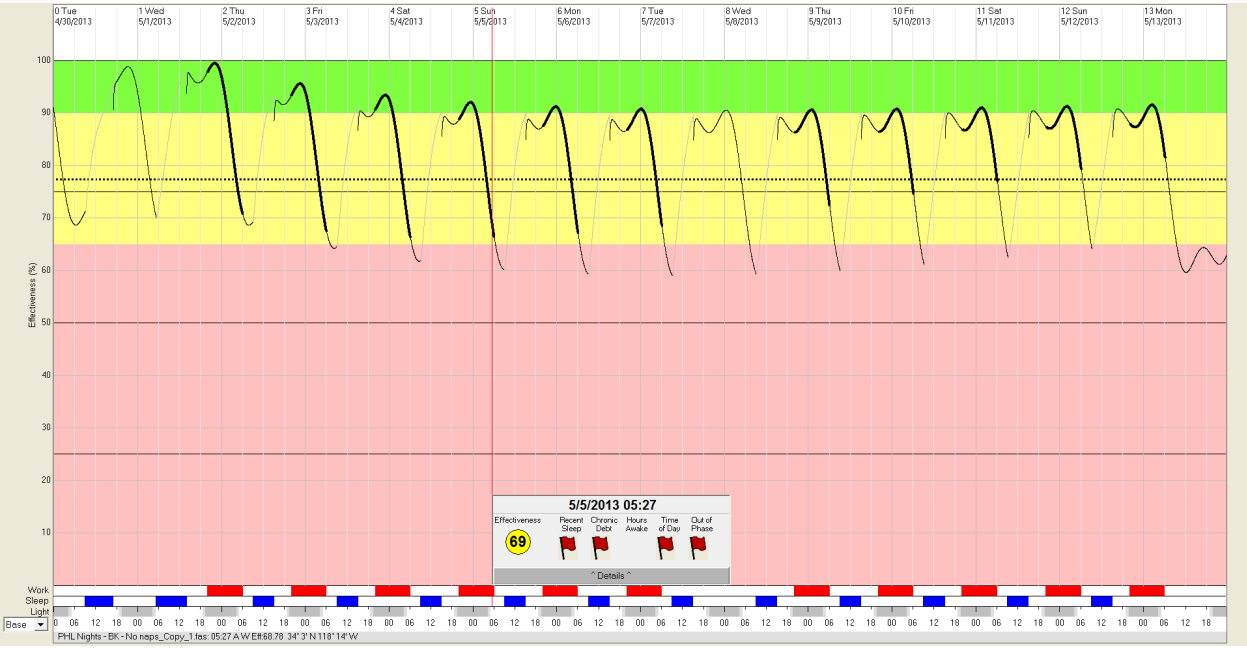

Figure 5.15 Schedule: PHL-BK _Nights − 2000 - 0600 – (10 Hrs work) (6 hrs sleep) no naps

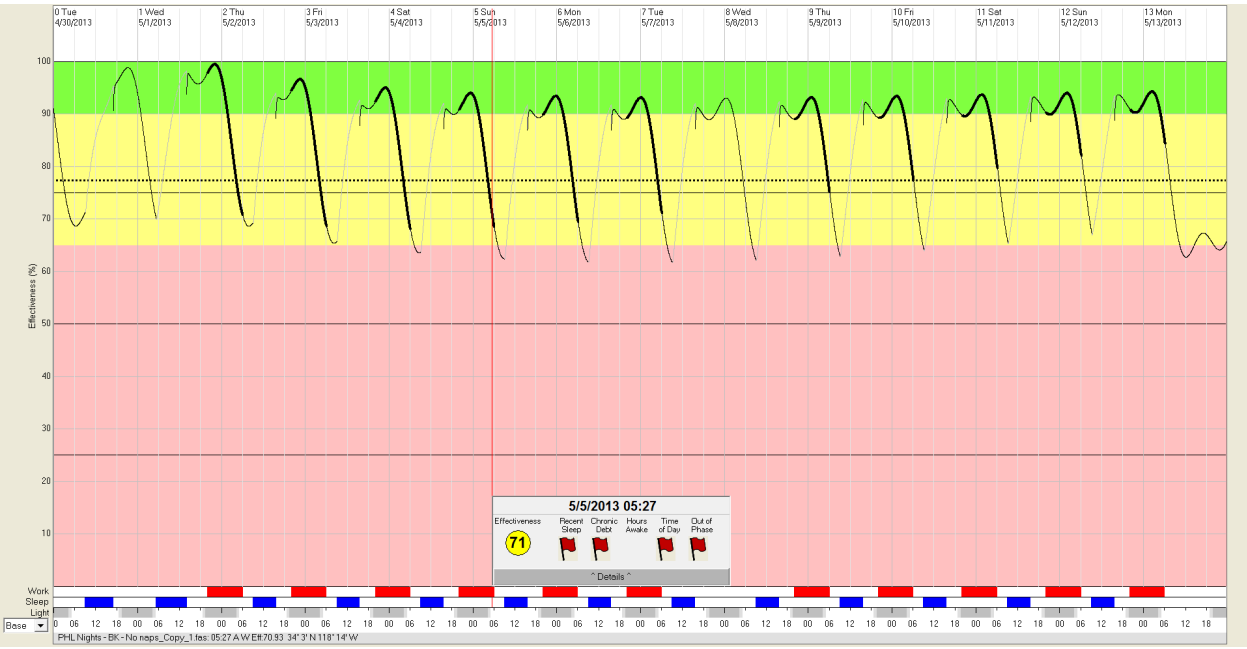

Figure 5.16 Schedule: PHL-BK _Nights − 2000 - 0600 – (10h work) (6.5h slp) no naps

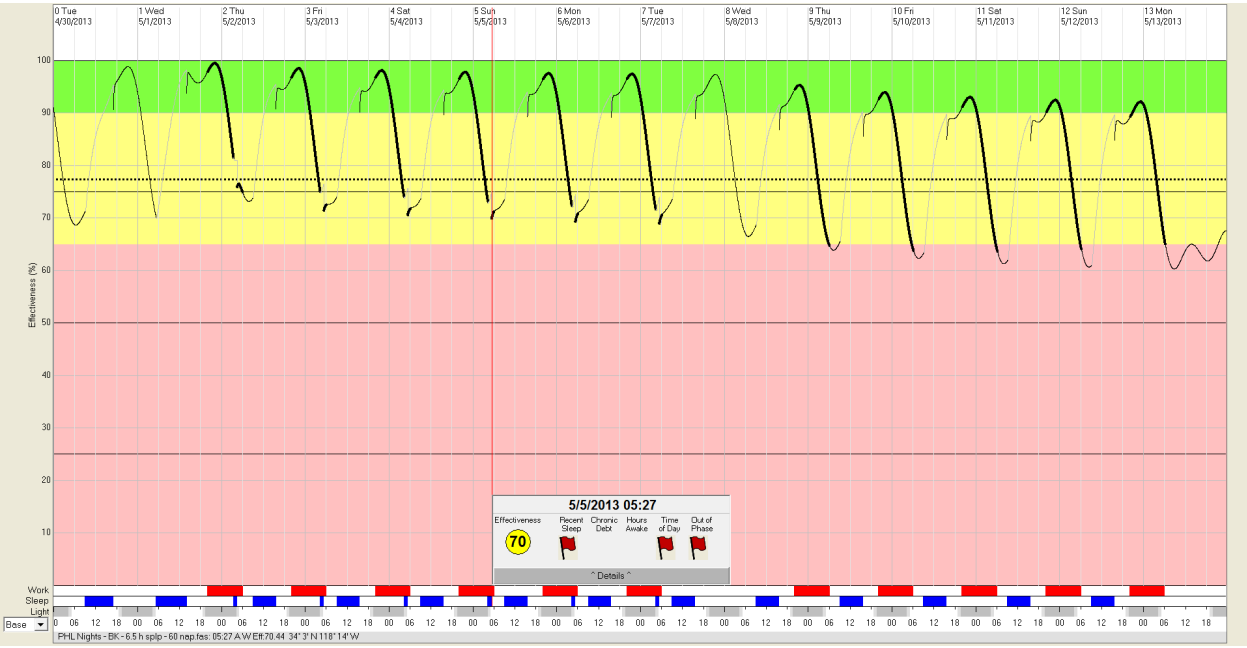

Figure 5.17 Schedule: PHL-BK _Nights − 2000 - 0600 – (10h work) (6.5h sleep) 60m nap

Overall, the addition of more sleep between shifts improves average effectiveness scores, and the addition of a nap during the work period also increases overall average effectiveness scores. In conclusion, if the operational requirements can be met, then inclusion of naps as part of the daily shift routine has a strong preventative effect.

6. CONCLUSION AND RECOMMENDATIONS

The present study has demonstrated that fatigue levels of individuals working shifts that incorporate fatigue countermeasures, such as naps and greater amounts of sleep during off hours, are more likely to have a lower risk for fatigue-related human factors-caused accidents.

Using the FRA approved modeling tool, a representative sample of work schedules were analyzed for likelihood of risk for fatigue-related accidents using FRA-recommended fatigue models. Results indicate that typical daytime schedules have the least risk of fatigue. Standard night shifts working from 11 p.m. to 6 a.m. had the greatest risk of fatigue. More importantly, by modifying the work schedules such that strategic naps were included in the work schedule on a regular basis, models indicate there is a significant reduction in fatigue risk that falls below, or closely approximates, the goal of ensuring that the work schedule does not "exceed the fatigue threshold more than 20 percent of the work time" (Gertler, DiFiore, and Raslear, 2013, p. 4).

The two main fatigue countermeasures shown to be most effective were:

1. Increasing the amount of sleep obtained between shifts
2. Instituting a scheduled workplace nap of either 60 or 90 minutes in length

Researchers (Sherry, Belenky, Folkard, 2005) have argued that the most effective method of reducing fatigue is to increase the amount of sleep, decrease the number of waking hours, and avoid working at times of the day when the propensity for sleep due to circadian rhythms is at its lowest. Sleep research has determined that sleep is managed by a homeostatic demand for sleep and the influence of the circadian rhythm. The homeostatic process operates such that the greater the number of hours awake, the greater the need for sleep. The circadian process is directly related to time of day. Unfortunately, the demands of the railroad operational environment sometimes necessitate the need to work during times when the demand for sleep may be at its peak.

Reviewing countermeasures using the FAST model shows that in most cases a rest period that includes a nap of 60-90 minutes would bring the overall effectiveness levels to nearly within acceptable limits, assuming that participants adhered to proper sleep hygiene prior to and during the time they worked the six midnight shifts. These results are displayed in Figure 9.3 and Table 9.3 in Appendix 1. More importantly, a break of 90 minutes sleep time brought the overall effectiveness levels well within the appropriate and recommended cutoffs and guidelines. These results are also displayed in Figure 9.4 and Table 9.4 in Appendix 1.

After reviewing the work schedules and operational demands of the baseline study participants, several suggested countermeasures were reviewed and considered. The operational practicality of these suggestions was reviewed by safety professionals working for the short line railroad association. The following countermeasures were considered most feasible:

- Use of on-duty naps to offset the negative impact of midnight hours
- Increase in the amount of off-duty sleep time
- Increase the amount of on-duty supervision to recognize fatigue
- Alteration of the start and end time of work shifts to avoid circadian rhythms
- Decrease the number of hours worked

6.1 Interventions

The interventions and countermeasures most likely to be used in the short line rail industry consist of three different approaches designed to minimize the risk of accident or injury due to fatigue.

6.2 Education

Employees should receive briefings and handouts with information pertaining to sleep hygiene. The benefits of sleep and the negative consequences of restricted and shortened sleep will be described. Study participants will complete a short quiz at pretest and then at the end of the intervention period designed to assess their knowledge of preventative sleep hygiene.

6.3 Close Supervision

Railroad supervisors should provide additional supervision and close monitoring during the course of work. Given the fact that the individuals are working under conditions for which there is a greater risk of human factors-caused accidents, railroad managers should provide closer supervision of their employees during this time. This could include frequent contact either in the form of visual inspection or phone during these times. For example, a supervisor could contact the operating crew at least twice by phone between 2 a.m. and 5 a.m., and a checklist can be included in the sleep diary to document the amount of that supervisory contact.

6.4 Adjusted Hours

In some cases, it may be possible to adjust hours that employees work to create a work situation more favorable to the alleviation of fatigue. For example, adjusting start times, end times etc., could be effective. One such adjustment would be to end work prior to 5 a.m. The adjustments will be dependent on the operational characteristics of the situation and demands of the work environment. But as a general principle, supervisors should think twice about scheduling work between the hours of 1 a.m. and 5 a.m., due to the higher risk of fatigue during these times.

6.5 Napping

Since additional sleep has a positive effect on alertness and reduces drowsiness and fatigue, we will endeavor to increase the amount of sleep. Accordingly, railroad operations that include opportunities for at least 60 minutes of opportunity for employees to sleep or nap during the hours between midnight and 5 a.m. will likely enjoy a lower risk of fatigue and human factors-caused accidents or incidents. The time period should afford the opportunity for at least a 30-minute nap and accommodate operational requirements necessary for the nap to be undertaken and the employee should not be expected to perform any operational duties. Facilities for the use of a bed may not be available, but comfortable seating and reclining should be expected. To ensure that the employee is actually able to take the nap, a designated naptime will be established for each operational setting expected to be used. Railroad supervisors should ensure that these conditions are met and, except for emergencies, interruptions will not occur. These designated nap times should be identified at the outset of the work period and known to study participants prior to beginning work.

A napping policy should be implemented with the following guidelines: 1) require a nap during on duty hours, not at the beginning or end of a shift; 2) set a designated time period, or time window, for the nap to occur during working hours; 3) set guidelines for when and where the nap will or can occur; 4) encourage napping in comfortable setting whenever possible; and 5) encourage napping in locomotive cabs as needed.

6.6 Time Off

In some cases, a worker, may, for whatever reason, request to be given time off due to fatigue. Just as in any operational circumstance, a person may develop excessive fatigue due to the necessities of daily living. In such a circumstance, an employee may request a day off to recover and recuperate in accordance with the operational rules and regulations. Such a request, or subsequent time off, will prohibit the person from participating in the study.

6.7 Behavioral Observation of Sleepiness

Observational measurements of fatigue in the workplace also should be performed by supervisory staff as needed. During the course of their daily duties supervisory staff and personnel will be in contact with study participants and will make observations of the fatigue and sleepiness of the study participants.

7. FUTURE RESEARCH

Discussing these options with the FRA and some of the ASLRRA study participants has resulted in a general recognition of the need to go forward with Short line railroads that want to participate in a larger scale study implementing and evaluating fatigue countermeasures that would include: education, additional supervision, adjustments to hours worked and a napping policy consistent with ones needed to reduce fatigue using the FAST model.

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9. APPENDICES

9.1 Appendix I. Data from Study Participants

Table 9.1 Schedule: JB-001 - Actual

	Start			End			Stats		
	Day	Date	Time	Day	Date	Time	Dur	Eff	%BCL
1	Sun	3/18/2012	14:00	Sun	3/18/2012	20:00	360	94.86	0.00
2	Mon	3/19/2012	12:00	Mon	3/19/2012	23:59	719	89.62	0.00
3	Tue	3/20/2012	12:00	Wed	3/21/2012	01:00	780	90.86	0.00
4	Wed	3/21/2012	13:00	Thu	3/22/2012	00:00	660	88.75	0.00
5	Thu	3/22/2012	12:00	Fri	3/23/2012	00:00	720	89.70	0.00
1	Sun	3/25/2012	14:00	Sun	3/25/2012	20:00	360	97.48	0.00
2	Wed	3/28/2012	13:00	Thu	3/29/2012	00:00	660	95.98	0.00
3	Thu	3/29/2012	12:00	Fri	3/30/2012	01:00	780	93.28	0.00
1	Sun	4/1/2012	14:00	Sun	4/1/2012	21:00	420	91.57	0.00
2	Mon	4/2/2012	12:00	Tue	4/3/2012	00:00	720	88.82	0.00
3	Tue	4/3/2012	12:00	Wed	4/4/2012	00:00	720	89.65	0.00
4	Wed	4/4/2012	13:00	Thu	4/5/2012	00:00	660	89.11	0.00
5	Thu	4/5/2012	12:00	Fri	4/6/2012	02:00	840	90.28	0.00
1	Mon	4/9/2012	12:00	Tue	4/10/2012	01:00	780	92.22	0.00
2	Tue	4/10/2012	12:00	Wed	4/11/2012	00:00	720	96.70	0.00
							659.93	91.62	0.00

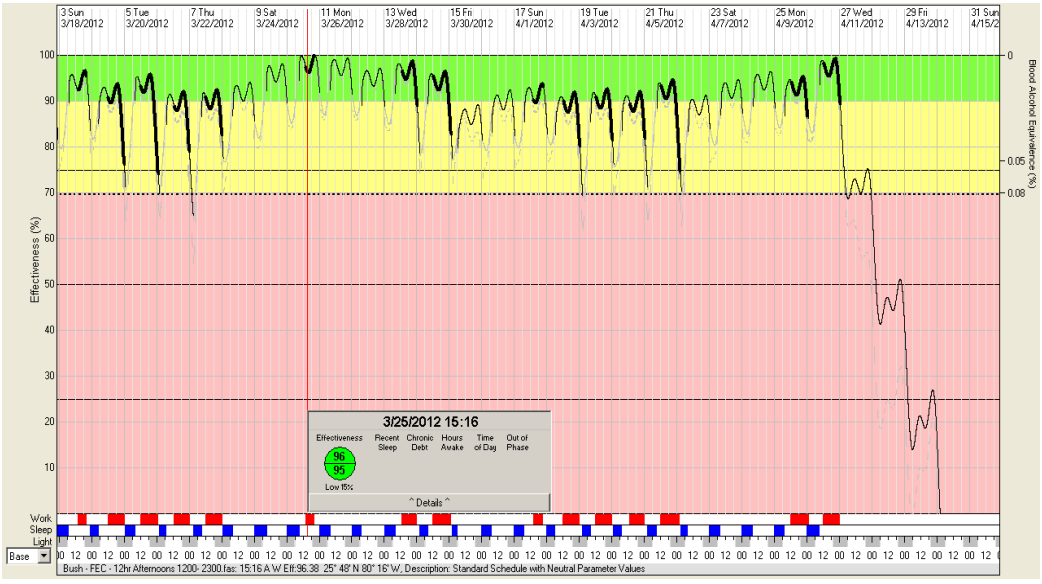

Figure 9.1 Effective analysis for schedule: JB001-Actual

Results of this schedule show no problems in that the person never falls below the cutoff of 70.

Table 9.2 Schedule: CP-002 - Actual

	Start			End			Stats		
	Day	Date	Time	Day	Date	Time	Dur	Eff	%BCL
1	Wed	3/14/2012	00:00	Wed	3/14/2012	07:00	420	79.51	0.00
2	Wed	3/14/2012	23:00	Thu	3/15/2012	08:00	540	73.64	0.00
3	Thu	3/15/2012	23:00	Fri	3/16/2012	08:00	540	71.92	53.70
4	Fri	3/16/2012	23:00	Sat	3/17/2012	08:00	540	70.98	62.59
5	Sat	3/17/2012	23:00	Sun	3/18/2012	08:00	540	70.71	61.67
1	Tue	3/20/2012	23:00	Wed	3/21/2012	08:00	540	79.18	10.56
2	Wed	3/21/2012	23:00	Thu	3/22/2012	08:00	540	78.65	31.11
3	Thu	3/22/2012	23:00	Fri	3/23/2012	08:00	540	80.10	25.74
4	Fri	3/23/2012	23:00	Sat	3/24/2012	08:00	540	80.87	23.70
5	Sat	3/24/2012	23:00	Sun	3/25/2012	08:00	540	82.02	20.19
1	Tue	3/27/2012	23:00	Wed	3/28/2012	09:00	600	75.64	41.50
2	Wed	3/28/2012	23:00	Thu	3/29/2012	08:00	540	82.04	21.11
3	Thu	3/29/2012	23:00	Fri	3/30/2012	09:00	600	82.25	23.17
4	Fri	3/30/2012	23:00	Sat	3/31/2012	09:00	600	83.87	17.83
1	Tue	4/3/2012	23:00	Wed	4/4/2012	08:00	540	83.79	15.56
2	Wed	4/4/2012	23:00	Thu	4/5/2012	09:00	600	85.42	12.67
3	Thu	4/5/2012	23:00	Fri	4/6/2012	08:00	540	90.83	0.00
4	Fri	4/6/2012	23:00	Sat	4/7/2012	08:00	540	91.00	0.00
							546	80.13	23.39

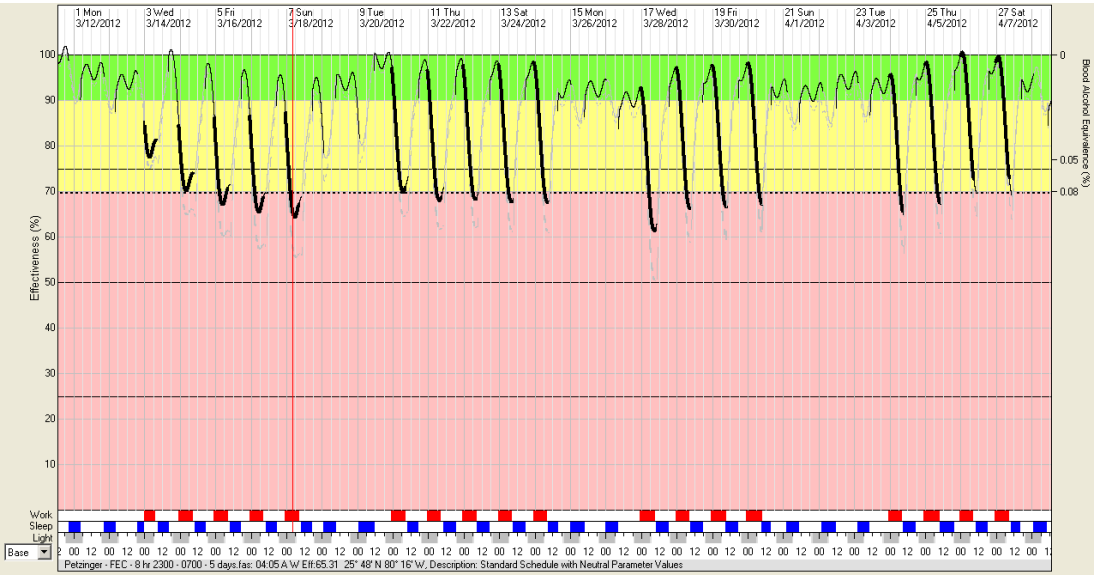

Figure 9.2 Effective analysis for schedule: CP002-Actual

The above schedule, working midnight beginning at 23:00 hours, shows mild evidence of fatigue with an average effectiveness score of 80.13 and %BCL of 23.39. Nine of the days profiled have effectiveness scores were below the threshold.

Table 9.3 Schedule: CP-002 – with 60 Minute naps

Start			End			Stats		
Day	Date	Time	Day	Date	Time	Dur	Eff	%BCL
Wed	3/14/2012	00:00	Wed	3/14/2012	07:00	420	84.29	0.00
Wed	3/14/2012	23:00	Thu	3/15/2012	08:00	540	79.30	0.00
Thu	3/15/2012	23:00	Fri	3/16/2012	08:00	540	76.56	0.00
Fri	3/16/2012	23:00	Sat	3/17/2012	08:00	540	74.78	3.33
Sat	3/17/2012	23:00	Sun	3/18/2012	08:00	540	73.52	25.00
Sun	3/18/2012	23:00	Mon	3/19/2012	08:00	540	72.58	32.78
Tue	3/20/2012	23:00	Wed	3/21/2012	08:00	540	77.26	0.00
Wed	3/21/2012	23:00	Thu	3/22/2012	08:00	540	74.97	0.00
Thu	3/22/2012	23:00	Fri	3/23/2012	08:00	540	74.75	0.00
Fri	3/23/2012	23:00	Sat	3/24/2012	08:00	540	74.56	0.00
Sat	3/24/2012	23:00	Sun	3/25/2012	08:00	540	74.38	6.48
Sun	3/25/2012	23:00	Mon	3/26/2012	09:00	600	74.50	12.00
Tue	3/27/2012	23:00	Wed	3/28/2012	09:00	600	75.49	0.00
Wed	3/28/2012	23:00	Thu	3/29/2012	08:00	540	75.11	0.00
Thu	3/29/2012	23:00	Fri	3/30/2012	09:00	600	74.93	0.00
Fri	3/30/2012	23:00	Sat	3/31/2012	09:00	600	74.57	9.50
Tue	4/3/2012	23:00	Wed	4/4/2012	08:00	540	70.64	42.59
Wed	4/4/2012	23:00	Thu	4/5/2012	09:00	600	70.99	38.00
Thu	4/5/2012	23:00	Fri	4/6/2012	08:00	540	71.43	38.52
Fri	4/6/2012	23:00	Sat	4/7/2012	08:00	540	70.27	52.41
					Average =	549.00	74.62	13.14

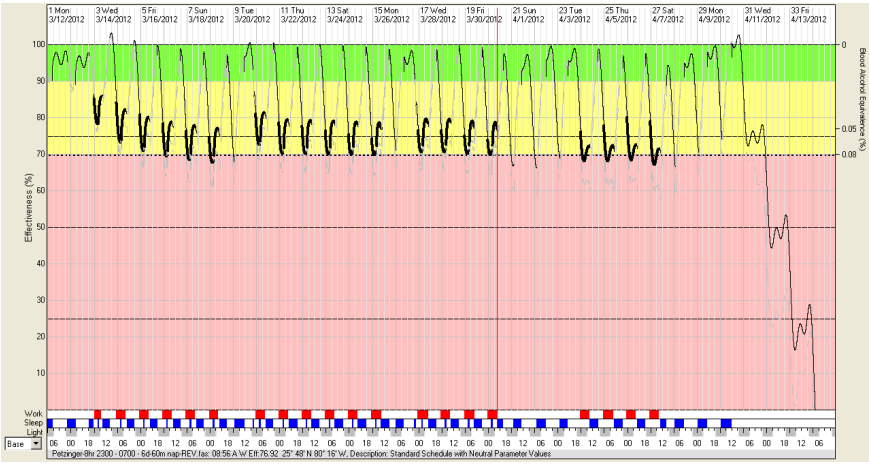

Figure 9.3 Effective analysis for schedule: CP002- with 60 minute naps

This figure shows that 60-minute naps have a positive effect, but do not completely eliminate the problem.

Table 9.4 Schedule CP-002 - Effectiveness of 90 Minute naps

Start			End			Stats		
Day	Date	Time	Day	Date	Time	Dur	Eff	%BCL
Wed	3/14/2012	00:00	Wed	3/14/2012	07:00	420	82.36	0.00
Wed	3/14/2012	23:00	Thu	3/15/2012	08:00	540	79.97	0.00
Thu	3/15/2012	23:00	Fri	3/16/2012	08:00	540	78.16	0.00
Fri	3/16/2012	23:00	Sat	3/17/2012	08:00	540	76.94	0.00
Sat	3/17/2012	23:00	Sun	3/18/2012	08:00	540	76.05	0.00
Sun	3/18/2012	23:00	Mon	3/19/2012	08:00	540	75.36	14.63
Tue	3/20/2012	23:00	Wed	3/21/2012	08:00	540	79.22	0.00
Wed	3/21/2012	23:00	Thu	3/22/2012	08:00	540	77.41	0.00
Thu	3/22/2012	23:00	Fri	3/23/2012	08:00	540	77.32	0.00
Fri	3/23/2012	23:00	Sat	3/24/2012	08:00	540	77.25	0.00
Sat	3/24/2012	23:00	Sun	3/25/2012	08:00	540	77.12	0.00
Sun	3/25/2012	23:00	Mon	3/26/2012	09:00	600	77.38	0.00
Tue	3/27/2012	23:00	Wed	3/28/2012	09:00	600	77.71	0.00
Wed	3/28/2012	23:00	Thu	3/29/2012	08:00	540	77.46	0.00
Thu	3/29/2012	23:00	Fri	3/30/2012	09:00	600	77.72	0.00
Fri	3/30/2012	23:00	Sat	3/31/2012	09:00	600	77.49	0.00
Tue	4/3/2012	23:00	Wed	4/4/2012	08:00	540	71.40	34.44
Wed	4/4/2012	23:00	Thu	4/5/2012	09:00	600	71.75	31.33
Thu	4/5/2012	23:00	Fri	4/6/2012	08:00	540	72.11	32.96
Fri	4/6/2012	23:00	Sat	4/7/2012	08:00	540	70.94	47.59
					Average	549	76.49	8.09

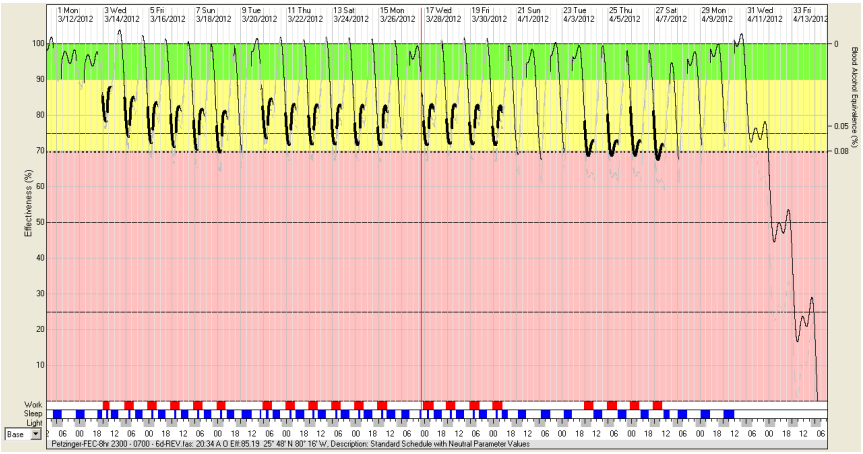

Figure 9.4 Effective analysis for schedule: CP002- with 90minute naps

These 90-minute naps achieve the desired effect for three out of the four weeks. Here you can see that the time spent below threshold drops to zero if person on the shift gets a 90-minute rest period with sleep starting at 3 a.m. The fourth week shows what happens if there are no naps. As can be seen, when the individual skips the 90-minute nap in week four, he again falls below the cutoff for a significant amount of time.

Table 9.5 Schedule: RS-003 - Actual

	Start			End			Stats		
	Day	Date	Time	Day	Date	Time	Dur	Eff	%BCL
1	Mon	3/19/2012	23:00	Tue	3/20/2012	08:00	540	80.88	0.00
2	Tue	3/20/2012	23:00	Wed	3/21/2012	08:00	540	76.55	0.00
3	Wed	3/21/2012	23:00	Thu	3/22/2012	08:00	540	77.16	0.00
4	Thu	3/22/2012	23:00	Fri	3/23/2012	08:00	540	75.05	0.00
5	Fri	3/23/2012	23:00	Sat	3/24/2012	08:00	540	74.25	0.00
6	Sat	3/24/2012	23:00	Sun	3/25/2012	08:00	540	72.82	0.00
1	Mon	3/26/2012	23:00	Tue	3/27/2012	09:00	600	78.73	0.00
2	Tue	3/27/2012	23:00	Wed	3/28/2012	09:00	600	77.96	0.00
3	Wed	3/28/2012	23:00	Thu	3/29/2012	08:00	540	76.84	0.00
4	Thu	3/29/2012	23:00	Fri	3/30/2012	09:00	600	74.09	0.00
1	Mon	4/2/2012	23:00	Tue	4/3/2012	08:00	540	83.54	0.00
2	Tue	4/3/2012	23:00	Wed	4/4/2012	08:00	540	78.65	0.00
3	Wed	4/4/2012	23:00	Thu	4/5/2012	09:00	600	74.91	0.00
4	Thu	4/5/2012	23:00	Fri	4/6/2012	08:00	540	76.97	0.00
5	Fri	4/6/2012	23:00	Sat	4/7/2012	08:00	540	79.18	0.00
						Average	**556.00**	**77.15**	**0.00**

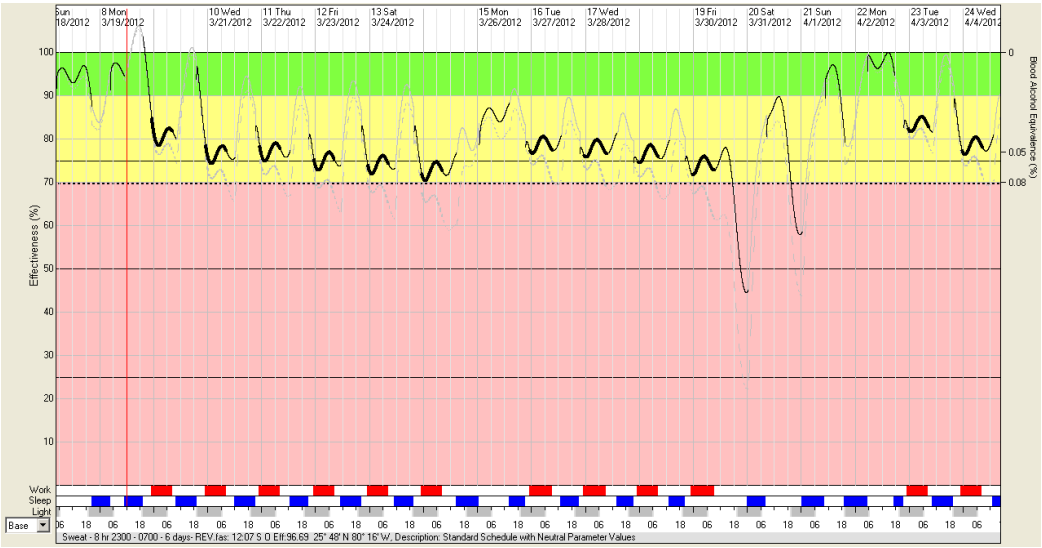

Figure 9.5 Effective analysis for schedule: RS003 – Actual

This six-day schedule was within the FRA limits because the participant obtained a regular eight hours of sleep prior to and during the time he was working. By establishing a solid anchor sleep of eight hours per night beforehand and then modifying sleep patterns so the eight hours off duty sleep was obtained just prior to working the midnight shift, the employee could manage much better.

Table 9.6 Schedule: RG-004 - Actual

	Start			End			Stats		
	Day	Date	Time	Day	Date	Time	Dur	Eff	%BCL
1	Wed	3/14/2012	00:00	Wed	3/14/2012	05:00	300	78.16	2.33
2	Wed	3/14/2012	17:00	Thu	3/15/2012	03:00	600	88.29	0.00
3	Thu	3/15/2012	16:00	Fri	3/16/2012	04:00	720	81.40	14.86
4	Fri	3/16/2012	16:00	Sat	3/17/2012	03:00	660	82.44	5.61
5	Sat	3/17/2012	19:00	Sun	3/18/2012	07:00	720	79.30	28.89
	Sun								
	Mon								
1	Tue	3/20/2012	16:00	Wed	3/21/2012	04:00	720	85.66	1.39
2	Wed	3/21/2012	16:00	Thu	3/22/2012	04:00	720	84.23	2.64
3	Thu	3/22/2012	16:00	Fri	3/23/2012	05:00	780	81.22	10.64
4	Fri	3/23/2012	16:00	Sat	3/24/2012	05:00	780	83.47	5.38
5	Sat	3/24/2012	18:00	Sun	3/25/2012	06:00	720	79.90	14.72
	Sun								
	Mon								
1	Tue	3/27/2012	17:00	Wed	3/28/2012	05:00	720	79.34	6.94
2	Wed	3/28/2012	17:00	Thu	3/29/2012	05:00	720	76.68	11.81
3	Thu	3/29/2012	17:00	Fri	3/30/2012	05:00	720	78.16	7.78
4	Fri	3/30/2012	17:00	Sat	3/31/2012	03:00	600	80.36	0.00
5	Sat	3/31/2012	18:00	Sun	4/1/2012	06:00	720	81.63	4.03
						Average	680.00	81.42	8.23

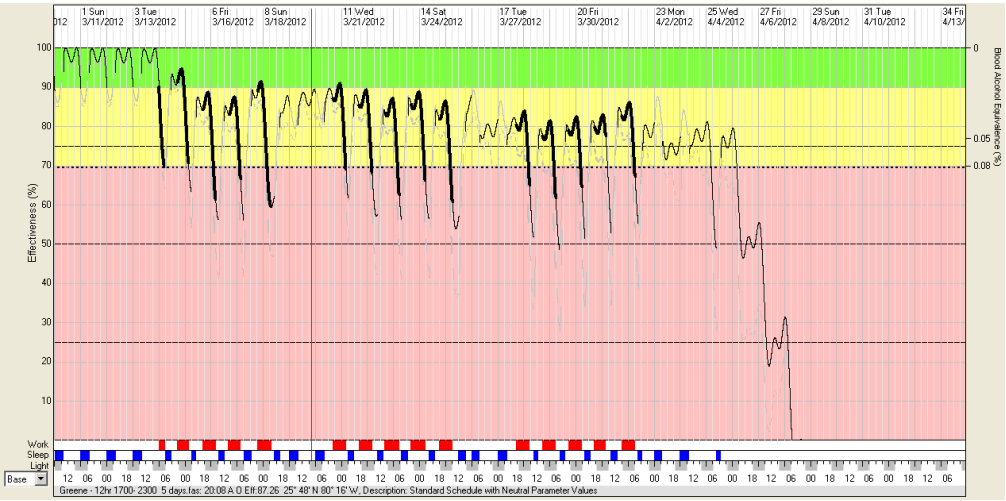

Figure 9.6 Effective analysis for schedule: RG004 – Actual

Appendix II. Study Participant Data - Day Shifts

Table 9.7 J001A – Actual

Start		**End**			**Stats**			
Day	Date	Time	Day	Date	Time	Dur	Eff	%BCL
Wed	7/11/2012+	03:00+	Wed+	7/11/2012+	17:00+	840	79.45	7.98
Thu	7/12/2012+	03:00+	Thu+	7/12/2012+	17:00+	840	82.11	2.50
Fri	7/13/2012+	03:00+	Fri+	7/13/2012+	17:00+	840	83.27	0.83
Mon	7/16/2012+	03:00+	Mon+	7/16/2012+	17:00+	840	91.41	0.00
Tue	7/17/2012+	03:00+	Tue+	7/17/2012+	15:00+	720	89.16	0.00
Wed	7/18/2012+	04:00+	Wed+	7/18/2012+	17:00+	780	89.43	0.00
Thu	7/19/2012+	03:00+	Thu+	7/19/2012+	13:00+	600	88.66	0.00
Fri	7/20/2012+	03:00+	Fri+	7/20/2012+	12:00+	540	84.70	0.00
Mon	7/23/2012+	03:00+	Mon+	7/23/2012+	17:00+	840	81.01	4.17
Tue	7/24/2012+	03:00+	Tue+	7/24/2012+	13:00+	600	81.53	4.17
Wed	7/25/2012+	03:00+	Wed+	7/25/2012+	16:00+	780	81.03	4.36
Thu	7/26/2012+	03:00+	Thu+	7/26/2012+	17:00+	840	83.54	0.83
Fri	7/27/2012+	03:00+	Fri+	7/27/2012+	17:00+	840	85.15	0.00
Mon	7/30/2012+	05:00+	Mon+	7/30/2012+	15:00+	600	89.90	0.00
Tue	7/31/2012+	03:00+	Tue+	7/31/2012+	12:00+	540	87.93	0.00
				736.00	**85.02**	**1.78**		

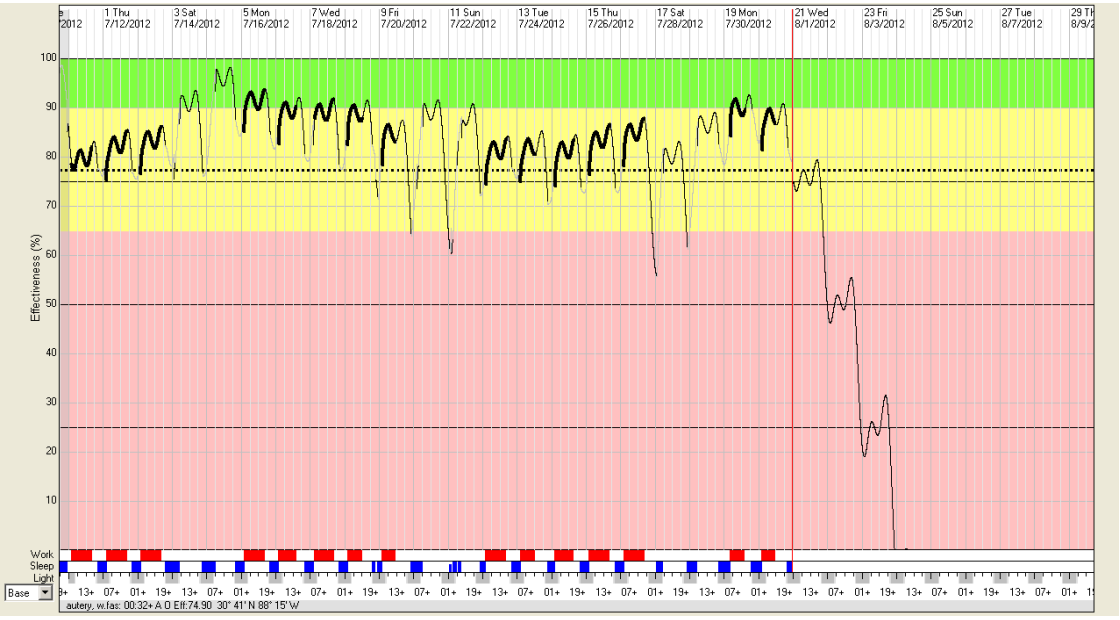

Figure 9.7 Effective analysis for schedule: J001A – Actual

Table 9.8 J002C – Actual

Start			**End**			**Stats**		
Day	Date	Time	Day	Date	Time	Dur	Eff	%BCL
Tue	2/14/2012+	08:00+	Tue+	2/14/2012+	12:00+	240	92.47	0.00
Tue	2/14/2012+	23:00+	Wed+	2/15/2012+	05:00+	360	80.56	43.89
Wed	2/15/2012+	22:00+	Thu+	2/16/2012+	04:00+	360	82.70	34.72
Thu	2/16/2012+	06:00+	Thu+	2/16/2012+	11:00+	300	81.55	7.67
Thu	2/16/2012+	22:00+	Fri+	2/17/2012+	05:00+	420	76.02	59.05
Fri	2/17/2012+	22:00+	Sat+	2/18/2012+	05:00+	420	74.72	62.62
Sat	2/18/2012+	22:00+	Sun+	2/19/2012+	05:00+	420	73.48	66.19
Sun	2/19/2012+	08:00+	Sun+	2/19/2012+	09:00+	60	78.60	25.00
Sun	2/19/2012+	22:00+	Mon+	2/20/2012+	05:00+	420	72.59	69.05
Thu	2/23/2012+	23:00+	Fri+	2/24/2012+	04:00+	300	82.80	28.00
Fri	2/24/2012+	07:00+	Fri+	2/24/2012+	10:00+	180	88.41	0.00
Fri	2/24/2012+	23:00+	Sat+	2/25/2012+	05:00+	360	78.67	52.78
Sat	2/25/2012+	08:00+	Sat+	2/25/2012+	09:00+	60	85.49	0.00
Tue	2/28/2012+	23:00+	Wed+	2/29/2012+	04:00+	300	82.24	32.00
Wed	2/29/2012+	08:00+	Wed+	2/29/2012+	09:00+	60	89.45	0.00
Sun	3/4/2012+	23:00+	Mon+	3/5/2012+	06:00+	420	83.12	35.71
Mon	3/5/2012+	23:00+	Tue+	3/6/2012+	04:00+	300	81.83	34.33
				292.94	**80.02**	**40.62**		

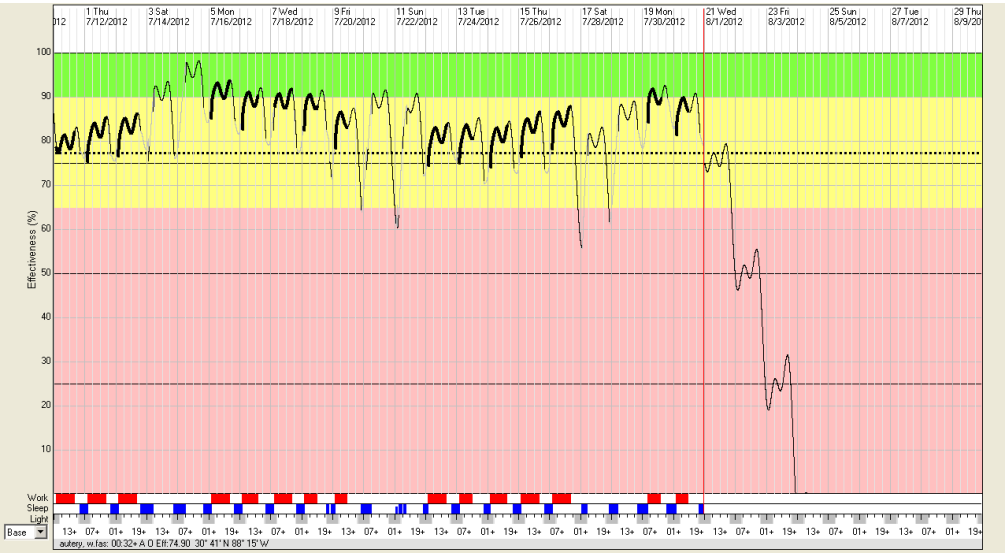

Figure 9.8 Effective analysis for schedule: J002C – Actual

This schedule shows that working days does not create significant risk for fatigue.

Table 9.9 J003 - Actual

Start		**End**		**Stats**				
Day	Date	Time	Day	Date	Time	Dur	Eff	%BCL
Wed	7/11/2012+	03:00+	Wed+	7/11/2012+	15:00+	720	82.63	0.14
Thu	7/12/2012+	03:00+	Thu+	7/12/2012+	15:00+	720	84.79	0.00
Fri	7/13/2012+	10:00+	Fri+	7/13/2012+	15:00+	300	95.75	0.00
Mon	7/16/2012+	15:00+	Tue+	7/17/2012+	02:00+	660	96.81	0.00
Tue	7/17/2012+	15:00+	Wed+	7/18/2012+	02:00+	660	97.75	0.00
Wed	7/18/2012+	15:00+	Thu+	7/19/2012+	02:00+	660	99.52	0.00
Thu	7/19/2012+	15:00+	Fri+	7/20/2012+	03:00+	720	97.31	0.00
Fri	7/20/2012+	15:00+	Sat+	7/21/2012+	04:00+	780	96.92	0.00
Mon	7/23/2012+	15:00+	Tue+	7/24/2012+	01:00+	600	99.82	0.00
Tue	7/24/2012+	15:00+	Wed+	7/25/2012+	03:00+	720	98.62	0.00
Wed	7/25/2012+	15:00+	Thu+	7/26/2012+	02:00+	660	99.05	0.00
Thu	7/26/2012+	15:00+	Fri+	7/27/2012+	03:00+	720	97.50	0.00
Fri	7/27/2012+	15:00+	Sat+	7/28/2012+	00:00+	540	98.90	0.00
Mon	7/30/2012+	15:00+	Tue+	7/31/2012+	05:00+	840	95.52	0.00
Tue	7/31/2012+	15:00+	Wed+	8/1/2012+	00:00+	540	97.27	0.00
				656.00	**95.70**		**0.01**	

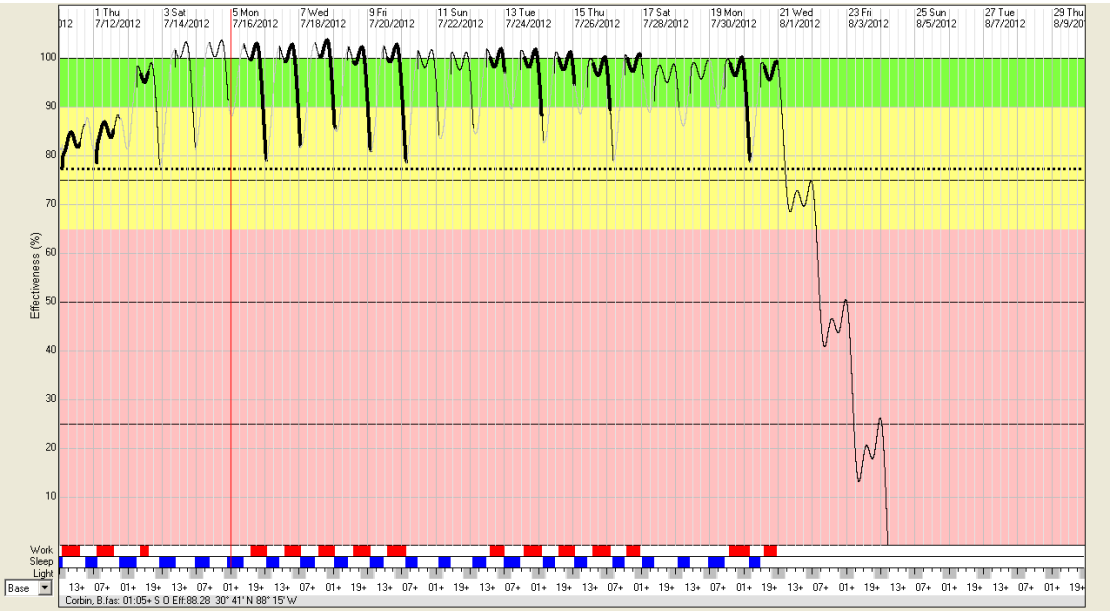

Figure 9.9 Effective analysis for schedule: J003 – Actual

This schedule, consisting of mostly days and afternoons, shows little or no risk of fatigue.

Table 9.10 J004 – Actual

Day	Date	Time	Day	Date	Time	Dur	Eff	%BCL			
Sat	8/20/2011+	15:00+	Sun+	8/21/2011+	02:00+	660	98.28	0.00			
Tue	8/23/2011+	15:00+	Wed+	8/24/2011+	01:00+	600	96.97	0.00			
Wed	8/24/2011+	15:00+	Thu+	8/25/2011+	02:00+	660	97.19	0.00			
Thu	8/25/2011+	15:00+	Fri+	8/26/2011+	03:00+	720	95.98	0.00			
Fri	8/26/2011+	15:00+	Sat+	8/27/2011+	03:00+	720	95.56	0.00			
Thu	9/1/2011+	15:00+	Fri+	9/2/2011+	00:00+	540	96.16	0.00			
Fri	9/2/2011+	15:00+	Fri+	9/2/2011+	22:00+	420	93.93	0.00			
Sat	9/3/2011+	15:00+	Sat+	9/3/2011+	21:00+	360	93.06	0.00			
Tue	9/6/2011+	15:00+	Tue+	9/6/2011+	22:00+	420	96.80	0.00			
Wed	9/7/2011+	15:00+	Wed+	9/7/2011+	23:00+	480	96.45	0.00			
Thu	9/8/2011+	15:00+	Fri+	9/9/2011+	00:00+	540	99.33	0.00			
						556.36	**96.50**	**0.00**			

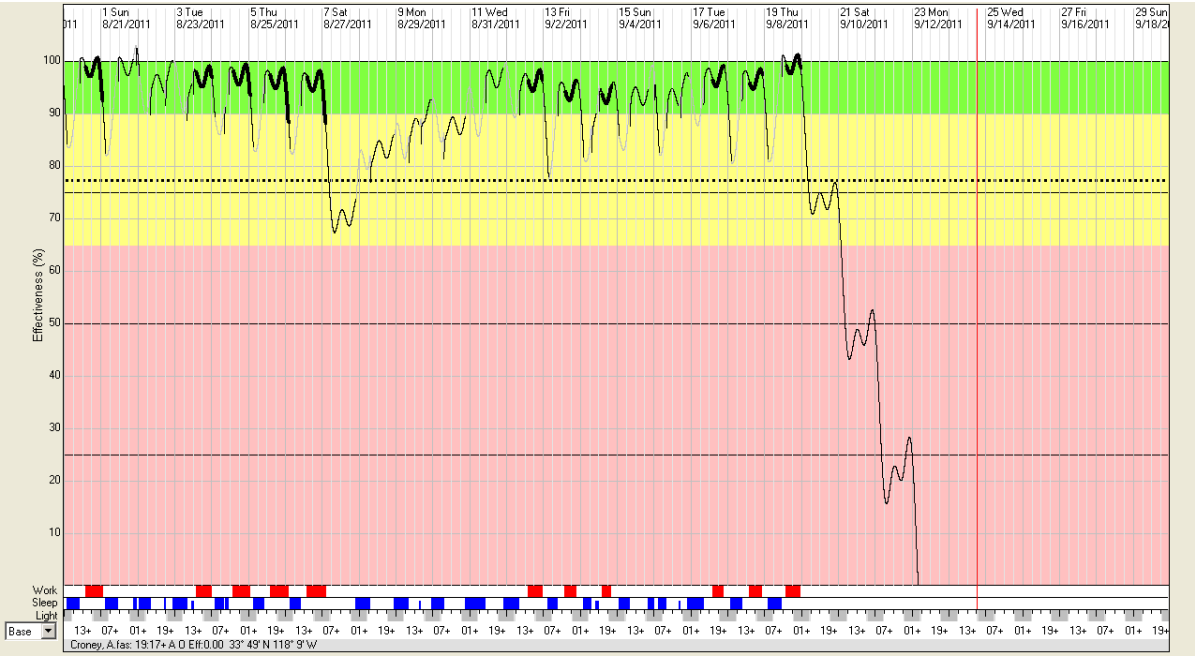

Figure 9.10 Effective analysis for schedule: J004 – Actual

This schedule, consisting of mostly days and afternoons, shows little or no risk of fatigue.

Table 9.11 J005 – Actual

Start			**End**			**Stats**		
Day	Date	Time	Day	Date	Time	Dur	Eff	%BCL
Tue	7/10/2012+	15:00+	Wed+	7/11/2012+	02:00+	660	98.28	0.00
Wed	7/11/2012+	15:00+	Thu+	7/12/2012+	02:00+	660	98.16	0.00
Thu	7/12/2012+	15:00+	Fri+	7/13/2012+	01:00+	600	99.40	0.00
Fri	7/13/2012+	15:00+	Sat+	7/14/2012+	00:00+	540	99.29	0.00
Mon	7/16/2012+	15:00+	Tue+	7/17/2012+	02:00+	660	97.07	0.00
Tue	7/17/2012+	15:00+	Wed+	7/18/2012+	02:00+	660	92.14	0.00
Wed	7/18/2012+	15:00+	Thu+	7/19/2012+	01:00+	600	97.94	0.00
Thu	7/19/2012+	15:00+	Fri+	7/20/2012+	02:00+	660	96.55	0.00
Mon	7/23/2012+	15:00+	Tue+	7/24/2012+	01:00+	600	96.37	0.00
Tue	7/24/2012+	15:00+	Wed+	7/25/2012+	03:00+	720	95.77	0.00
Wed	7/25/2012+	15:00+	Thu+	7/26/2012+	02:00+	660	95.95	0.00
Thu	7/26/2012+	15:00+	Fri+	7/27/2012+	04:00+	780	92.09	1.03
Fri	7/27/2012+	15:00+	Sat+	7/28/2012+	00:00+	540	93.09	0.00
Mon	7/30/2012+	15:00+	Tue+	7/31/2012+	06:00+	900	88.74	11.78
Tue	7/31/2012+	15:00+	Wed+	8/1/2012+	02:00+	660	92.80	0.00
Wed	8/1/2012+	15:00+	Thu+	8/2/2012+	02:00+	660	67.74	100.00
						660.00	**93.59**	**7.33**

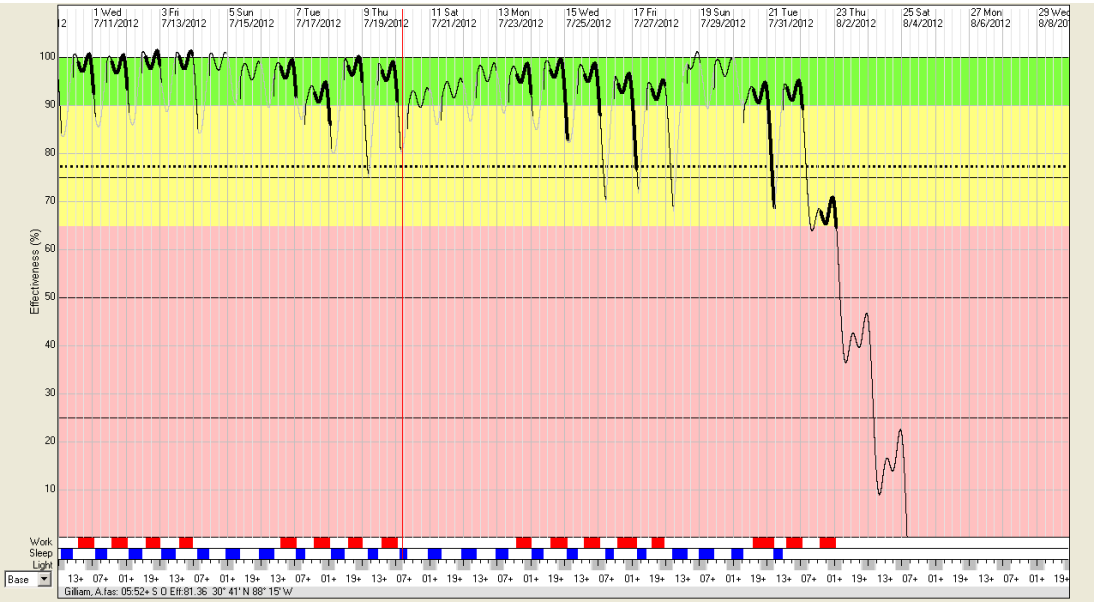

Figure 9.11 Effective analysis for schedule: J005 – Actual

This person worked afternoons with an average of 660.50 minutes per day with about 7.33% of time spent below critical cutoff, which is acceptable and within limits.

Table 9.12 J0011 - Actual

Start			**End**			**Stats**		
Day	Date	Time	Day	Date	Time	Dur	Eff	%BCL
Thu	7/12/2012+	06:00+	Thu+	7/12/2012+	18:00+	720	84.55	0.00
Fri	7/13/2012+	11:00+	Fri+	7/13/2012+	20:00+	540	91.09	0.00
Tue	7/17/2012+	05:00+	Tue+	7/17/2012+	19:00+	840	88.71	0.00
Wed	7/18/2012+	04:00+	Wed+	7/18/2012+	16:00+	720	85.92	0.00
Thu	7/19/2012+	06:00+	Thu+	7/19/2012+	17:00+	660	89.64	0.00
Fri	7/20/2012+	05:00+	Fri+	7/20/2012+	18:00+	780	90.00	0.00
Sun	7/22/2012+	06:00+	Sun+	7/22/2012+	19:00+	780	93.82	0.00
Mon	7/23/2012+	05:00+	Mon+	7/23/2012+	17:00+	720	93.38	0.00
Tue	7/24/2012+	06:00+	Tue+	7/24/2012+	16:00+	600	93.13	0.00
Wed	7/25/2012+	04:00+	Wed+	7/25/2012+	16:00+	720	91.11	0.00
Thu	7/26/2012+	06:00+	Thu+	7/26/2012+	17:00+	660	92.75	0.00
Fri	7/27/2012+	03:00+	Fri+	7/27/2012+	16:00+	780	89.80	0.00
Tue	7/31/2012+	11:00+	Tue+	7/31/2012+	20:00+	540	97.85	0.00
Wed	8/1/2012+	11:00+	Thu+	8/2/2012+	00:00+	780	93.71	0.00
Thu	8/2/2012+	12:00+	Thu+	8/2/2012+	21:00+	540	97.57	0.00
Fri	8/3/2012+	06:00+	Fri+	8/3/2012+	22:00+	960	90.33	0.00
Sun	8/5/2012+	06:00+	Sun+	8/5/2012+	18:00+	720	91.73	0.00
Mon	8/6/2012+	04:00+	Mon+	8/6/2012+	16:00+	720	87.45	0.00
Tue	8/7/2012+	06:00+	Tue+	8/7/2012+	19:00+	780	89.76	0.00
Wed	8/8/2012+	05:00+	Wed+	8/8/2012+	20:00+	900	91.37	0.00
Thu	8/9/2012+	10:00+	Thu+	8/9/2012+	19:00+	540	96.56	0.00
Fri	8/10/2012+	13:00+	Sat+	8/11/2012+	02:00+	780	90.60	15.38
						717.27	**91.150.76**	

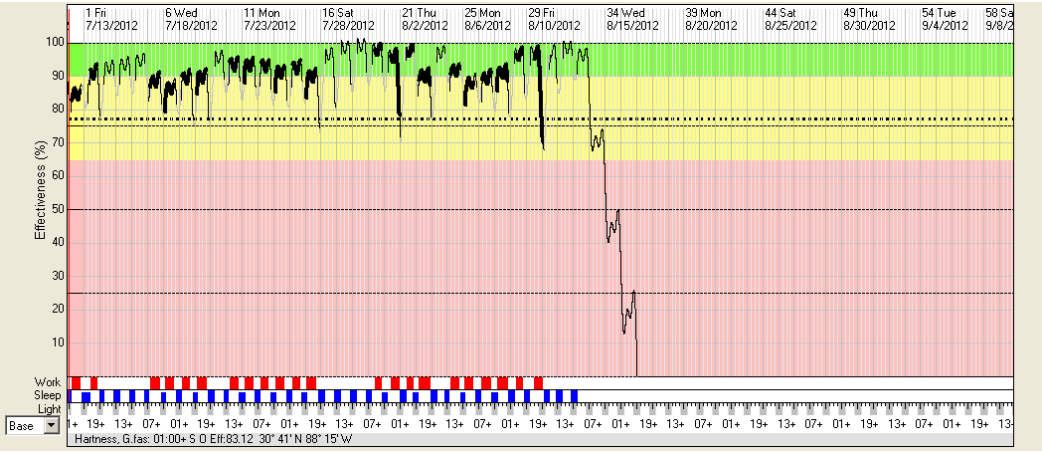

Figure 9.12 Effective analysis for schedule: J0011 – Actual

This person worked an average of 717.27 minutes per day with about 0.76% of time spent below critical cutoff, which is acceptable.

Table 9.13 J0013 - Actual

Day	Date	Time	Day	Date	Time	Dur	Eff	%BCL
Mon	4/30/2012	19:00	Tue	5/1/2012	03:00	480	89.17	12.08
Tue	5/1/2012	19:00	Wed	5/2/2012	03:00	480	88.22	10.63
Wed	5/2/2012	19:00	Thu	5/3/2012	04:00	540	86.11	18.70
Thu	5/3/2012	19:00	Fri	5/4/2012	04:00	540	88.70	10.93
Fri	5/4/2012	19:00	Sat	5/5/2012	04:00	540	88.18	9.44
Mon	5/7/2012	19:00	Tue	5/8/2012	04:00	540	92.41	0.00
Tue	5/8/2012	19:00	Wed	5/9/2012	03:00	480	92.61	0.00
Wed	5/9/2012	19:00	Thu	5/10/2012	03:00	480	89.41	0.00
Thu	5/10/2012	19:00	Fri	5/11/2012	03:00	480	87.45	0.00
Fri	5/11/2012	19:00	Sat	5/12/2012	03:00	480	90.98	0.00
Mon	5/14/2012	19:00	Tue	5/15/2012	03:00	480	89.16	0.00
Tue	5/15/2012	19:00	Wed	5/16/2012	04:00	540	89.01	0.00
Wed	5/16/2012	19:00	Thu	5/17/2012	04:00	540	89.30	0.00
Thu	5/17/2012	19:00	Fri	5/18/2012	03:00	480	89.88	0.00
Fri	5/18/2012	19:00	Sat	5/19/2012	03:00	480	91.67	0.00
Mon	5/21/2012	19:00	Tue	5/22/2012	03:00	480	88.33	0.00
Tue	5/22/2012	19:00	Wed	5/23/2012	03:00	480	89.16	0.00
Wed	5/23/2012	19:00	Thu	5/24/2012	03:00	480	89.48	0.00
Thu	5/24/2012	19:00	Fri	5/25/2012	03:00	480	80.34	0.00
Fri	5/25/2012	19:00	Sat	5/26/2012	03:00	480	87.80	0.00
Tue	5/29/2012	19:00	Wed	5/30/2012	05:00	600	91.23	0.00
Wed	5/30/2012	19:00	Thu	5/31/2012	05:00	600	86.86	5.17
Thu	5/31/2012	19:00	Fri	6/1/2012	03:00	480	63.70	100.00
						506.09.	**87.85**	**7.14**

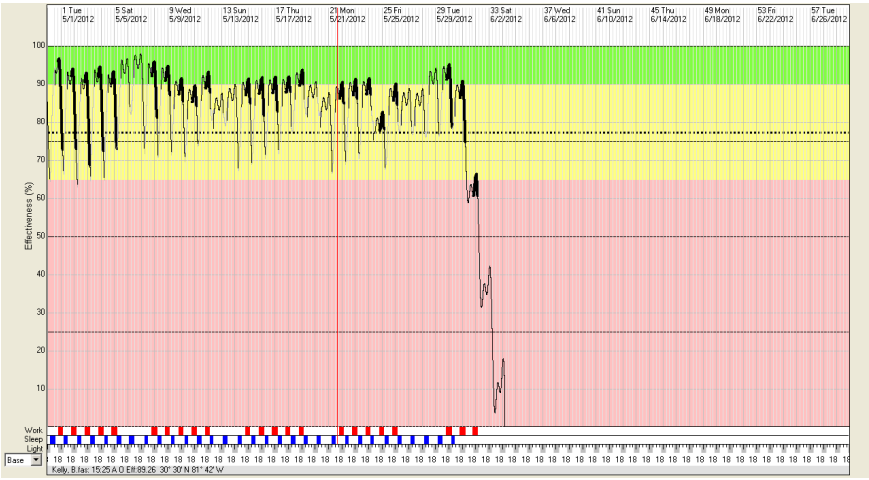

Figure 9.13 Effective analysis for schedule: J0013 – Actual

Starts off with nights and then goes to days. Acceptable fatigue levels with only 7.14% of time below critical cutoff levels.

Table 9.14 J0014 - Actual

Start			End			Stats		
Day	**Date**	**Time**	**Day**	**Date**	**Time**	**Dur**	**Eff**	**%BCL**
Wed	3/14/2012+	16:00+	Thu+	3/15/2012+	00:00+	480	96.72	0.00
Thu	3/15/2012+	16:00+	Fri+	3/16/2012+	00:00+	480	95.80	0.00
Fri	3/16/2012+	15:00+	Sat+	3/17/2012+	00:00+	540	97.22	0.00
Mon	3/19/2012+	15:00+	Tue+	3/20/2012+	00:00+	540	96.18	0.00
Tue	3/20/2012+	16:00+	Wed+	3/21/2012+	00:00+	480	94.94	0.00
Wed	3/21/2012+	16:00+	Thu+	3/22/2012+	00:00+	480	96.57	0.00
Thu	3/22/2012+	15:00+	Fri+	3/23/2012+	02:00+	660	94.34	0.00
Fri	3/23/2012+	15:00+	Sat+	3/24/2012+	00:00+	540	94.53	0.00
Mon	3/26/2012+	12:00+	Tue+	3/27/2012+	00:00+	720	92.24	0.00
Tue	3/27/2012+	15:00+	Wed+	3/28/2012+	00:00+	540	90.56	0.00
Wed	3/28/2012+	15:00+	Thu+	3/29/2012+	00:00+	540	91.10	0.00
Thu	3/29/2012+	15:00+	Fri+	3/30/2012+	00:00+	540	92.77	0.00
Fri	3/30/2012+	15:00+	Sat+	3/31/2012+	00:00+	540	91.73	0.00
Sat	3/31/2012+	15:00+	Sat+	3/31/2012+	23:00+	480	90.32	0.00
Tue	4/3/2012+	15:00+	Wed+	4/4/2012+	00:00+	540	91.21	0.00
Wed	4/4/2012+	15:00+	Wed+	4/4/2012+	23:00+	480	95.68	0.00
Thu	4/5/2012+	15:00+	Fri+	4/6/2012+	00:00+	540	94.08	0.00
Fri	4/6/2012+	15:00+	Sat+	4/7/2012+	00:00+	540	94.60	0.00
Sat	4/7/2012+	15:00+	Sun+	4/8/2012+	00:00+	540	91.07	0.00
Tue	4/10/2012+	15:00+	Wed+	4/11/2012+	00:00+	540	84.19	6.67
Wed	4/11/2012+	15:00+	Thu+	4/12/2012+	00:00+	540	89.02	0.00
						537.14.	**93.03**	**0.32**

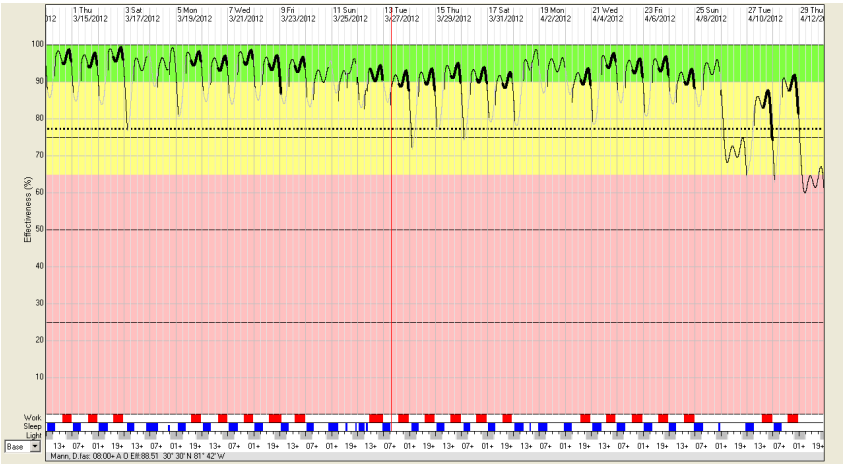

Figure 9.14 Effective analysis for schedule: J0014 – Actual

This person worked an average of 537.14 minutes per day with about 0% time spent below critical cutoff, which is acceptable. Mostly days. Within limits.

Table 9.15 J0015 - Actual

Day	Date	Time	Day	Date	Time	Dur	Eff	%BCL
Sat	5/12/2012	04:00	Sat	5/12/2012	12:00	480	79.50	0.00
Mon	5/14/2012	22:00	Tue	5/15/2012	02:00	240	98.79	0.00
Tue	5/15/2012	03:00	Tue	5/15/2012	07:00	240	80.43	20.83
Tue	5/15/2012	08:00	Tue	5/15/2012	10:00	120	80.52	10.00
Thu	5/17/2012	07:00	Thu	5/17/2012	16:00	540	85.37	0.00
Fri	5/18/2012	23:00	Sat	5/19/2012	10:00	660	83.46	45.00
Wed	5/23/2012	12:00	Thu	5/24/2012	02:00	840	93.10	0.00
Thu	5/24/2012	13:00	Fri	5/25/2012	00:00	660	93.21	0.00
Sat	5/26/2012	06:00	Sat	5/26/2012	14:00	480	82.24	0.00
Mon	5/28/2012	00:00	Mon	5/28/2012	06:00	360	86.98	18.06
Wed	5/30/2012	05:00	Wed	5/30/2012	17:00	720	76.61	75.69
						485.45	**85.71**	**18.15**

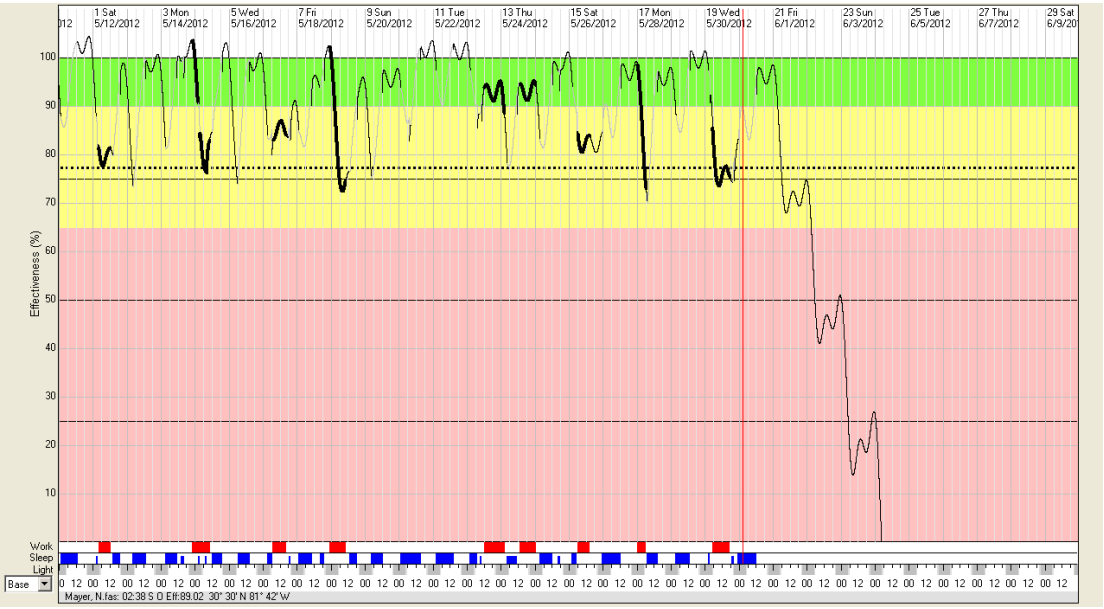

Figure 9.15 Effective analysis for schedule: J0015 – Actual

This study participant appears to be working an Extraboard with variable start and end times. This person worked an average of 485 minutes per day with about 18% of time spent below critical cutoff, which is acceptable.

Table 9.16 J0016 - Actual

Start			End			Stats		
Day	**Date**	**Time**	**Day**	**Date**	**Time**	**Dur**	**Eff**	**%BCL**
Sat	8/20/2011+	07:00+	Sat+	8/20/2011+	19:00+	720	91.64	0.00
Sun	8/21/2011+	08:00+	Sun+	8/21/2011+	16:00+	480	93.07	0.00
Mon	8/22/2011+	08:00+	Mon+	8/22/2011+	21:00+	780	93.60	0.00
Thu	8/25/2011+	01:00+	Thu+	8/25/2011+	13:00+	720	81.55	0.00
Fri	8/26/2011+	07:00+	Fri+	8/26/2011+	19:00+	720	93.04	0.00
Sat	8/27/2011+	07:00+	Sat+	8/27/2011+	14:00+	420	92.67	0.00
Sun	8/28/2011+	08:00+	Sun+	8/28/2011+	18:00+	600	97.86	0.00
Mon	8/29/2011+	08:00+	Mon+	8/29/2011+	12:00+	240	96.19	0.00
Mon	8/29/2011+	13:00+	Mon+	8/29/2011+	19:00+	360	97.78	0.00
Thu	9/1/2011+	01:00+	Thu+	9/1/2011+	12:00+	660	67.03	100.00
Fri	9/2/2011+	07:00+	Fri+	9/2/2011+	16:00+	540	88.06	0.00
Sat	9/3/2011+	07:00+	Sat+	9/3/2011+	19:00+	720	93.22	0.00
						580.00	**9.68**	**9.48**

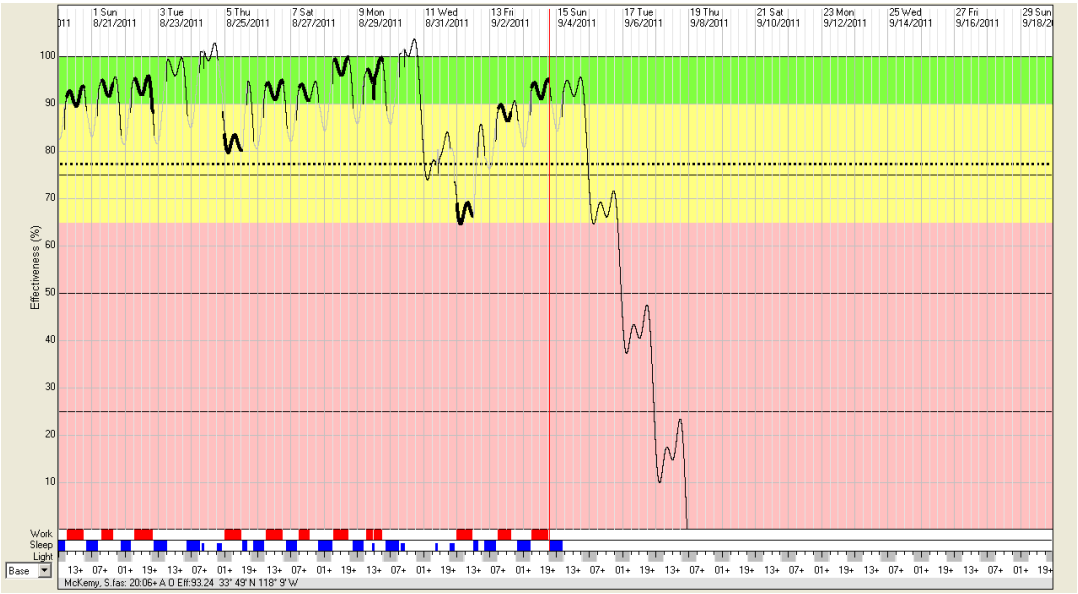

Figure 9.16 Effective analysis for schedule: J0016 – Actual

This study participant worked an average of 580.00 minutes per day with a 7:00 or 8:00 a.m. start time most days. With the exception of one night and no appreciable fatigue, as this individual spent 9.48% of the time below critical cutoff.

Table 9.17 J0017 - Actual

Start			End			Stats		
Day	**Date**	**Time**	**Day**	**Date**	**Time**	**Dur**	**Eff**	**%BCL**
Fri	11/11/2011	07:00	Fri	11/11/2011	15:00	480	94.02	0.00
Mon	11/14/2011	07:00	Mon	11/14/2011	16:00	540	96.59	0.00
Tue	11/15/2011	07:00	Tue	11/15/2011	15:00	480	96.14	0.00
Wed	11/16/2011	07:00	Wed	11/16/2011	15:00	480	96.43	0.00
Thu	11/17/2011	07:00	Thu	11/17/2011	15:00	480	97.64	0.00
Fri	11/18/2011	07:00	Fri	11/18/2011	15:00	480	96.49	0.00
Mon	11/21/2011	07:00	Mon	11/21/2011	15:00	480	97.62	0.00
Tue	11/22/2011	07:00	Tue	11/22/2011	15:00	480	96.59	0.00
Wed	11/23/2011	07:00	Wed	11/23/2011	15:00	480	97.14	0.00
						486.67	**96.52**	**0.00**

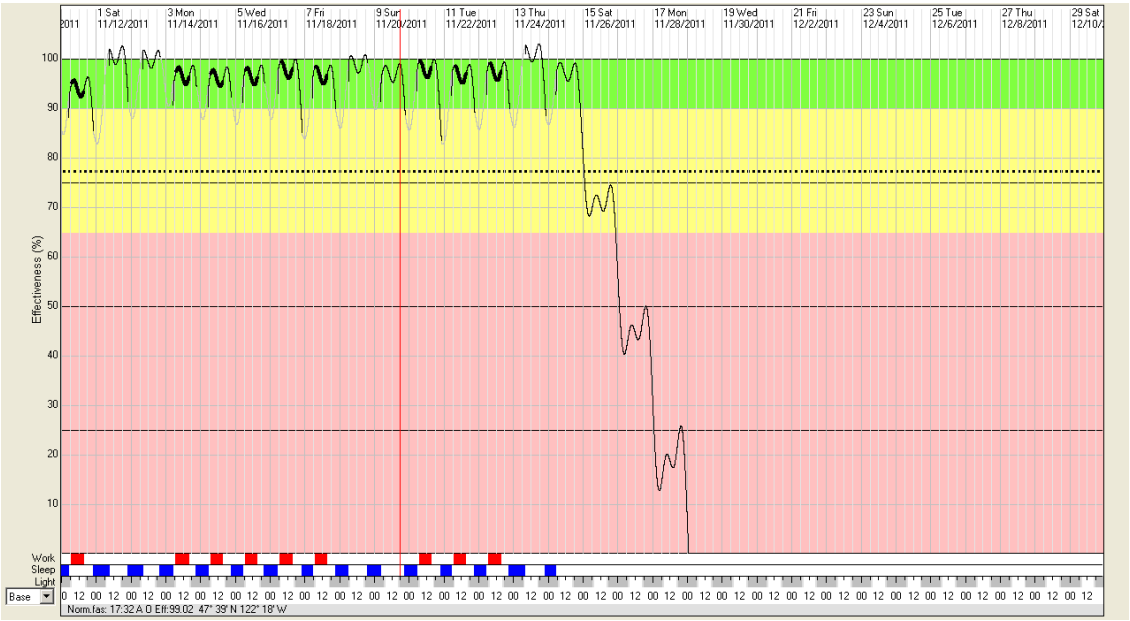

Figure 9.17 Effective analysis for schedule: J0017 – Actual

This study participant worked an average of 486.67 minutes per day with a 7:00 a.m. start time. No appreciable fatigue, as this individual spent 0% time below critical cutoff.

Table 9.18 J0021 - Actual

Start			End			Stats		
Day	**Date**	**Time**	**Day**	**Date**	**Time**	**Dur**	**Eff**	**%BCL**
Thu	3/15/2012+	06:00+	Thu+	3/15/2012+	14:00+	480	93.73	0.00
Mon	3/26/2012+	06:00+	Mon+	3/26/2012+	22:00+	960	90.89	0.00
Tue	3/27/2012+	06:00+	Tue+	3/27/2012+	17:00+	660	87.19	0.00
Wed	3/28/2012+	06:00+	Wed+	3/28/2012+	14:00+	480	88.25	0.00
Thu	3/29/2012+	06:00+	Thu+	3/29/2012+	14:00+	480	88.69	0.00
Sun	4/1/2012+	06:00+	Sun+	4/1/2012+	14:00+	480	93.32	0.00
Mon	4/2/2012+	06:00+	Mon+	4/2/2012+	14:00+	480	92.38	0.00
Tue	4/3/2012+	06:00+	Tue+	4/3/2012+	14:00+	480	93.00	0.00
Wed	4/4/2012+	06:00+	Wed+	4/4/2012+	14:00+	480	93.55	0.00
Thu	4/5/2012+	06:00+	Thu+	4/5/2012+	14:00+	480	92.13	0.00
Sun	4/8/2012+	06:00+	Sun+	4/8/2012+	14:00+	480	96.16	0.00
Mon	4/9/2012+	06:00+	Mon+	4/9/2012+	22:00+	960	90.40	0.00
Tue	4/10/2012+	06:00+	Tue+	4/10/2012+	15:00+	540	92.20	0.00
						572.31	**91.44**	**0.00**

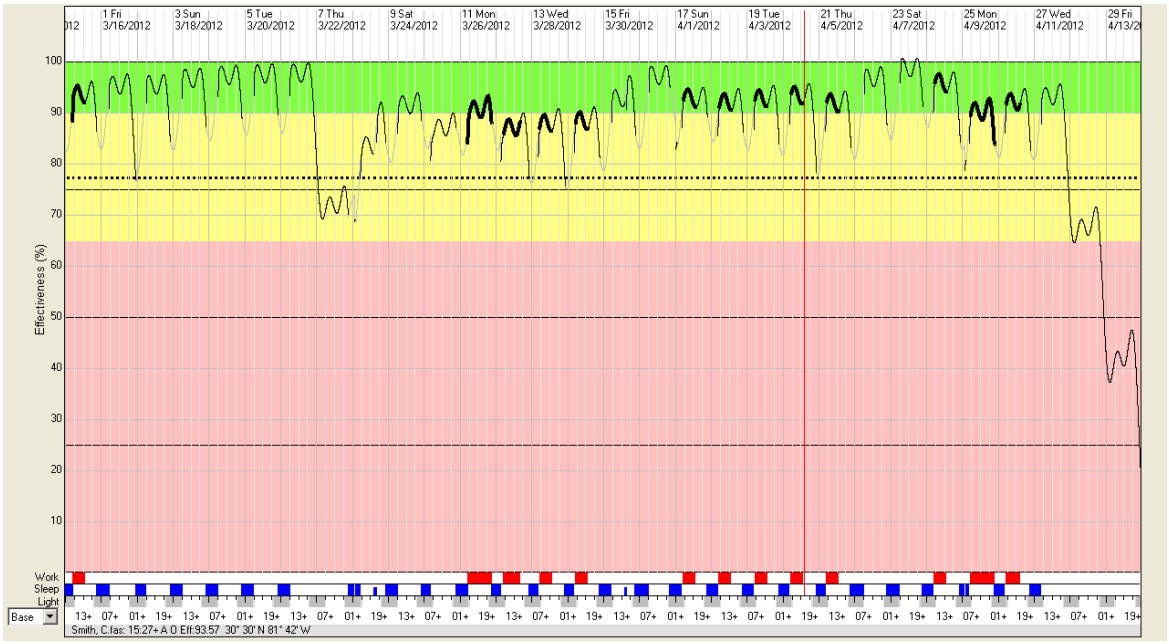

Figure 9.18 Effective analysis for schedule: J0021 – Actual

This study participant worked an average of 572.31 minutes per day with a 6:00 a.m. start time. No appreciable fatigue, as this individual spent 0% time below critical cutoff.

Appendix III. Study Participant Data - Night Shifts

Table 9.191 J0006 - Actual

Start			End			Stats		
Day	**Date**	**Time**	**Day**	**Date**	**Time**	**Dur**	**Eff**	**%BCL**
Wed	3/14/2012+	01:00+	Wed+	3/14/2012+	05:00+	240	70.45	100.00
Wed	3/14/2012+	17:00+	Thu+	3/15/2012+	05:00+	720	74.63	54.44
Thu	3/15/2012+	16:00+	Fri+	3/16/2012+	04:00+	720	71.01	55.56
Fri	3/16/2012+	16:00+	Sat+	3/17/2012+	03:00+	660	70.72	54.55
Sat	3/17/2012+	19:00+	Sun+	3/18/2012+	07:00+	720	68.20	69.31
Tue	3/20/2012+	16:00+	Wed+	3/21/2012+	04:00+	720	87.35	20.69
Wed	3/21/2012+	17:00+	Thu+	3/22/2012+	04:00+	660	81.62	28.18
Thu	3/22/2012+	17:00+	Fri+	3/23/2012+	05:00+	720	78.93	32.92
Fri	3/23/2012+	16:00+	Sat+	3/24/2012+	05:00+	780	79.59	28.08
Sat	3/24/2012+	18:00+	Sun+	3/25/2012+	06:00+	720	76.80	37.64
Tue	3/27/2012+	17:00+	Wed+	3/28/2012+	05:00+	720	74.87	62.92
Wed	3/28/2012+	17:00+	Thu+	3/29/2012+	05:00+	720	70.85	100.00
Thu	3/29/2012+	17:00+	Fri+	3/30/2012+	05:00+	720	74.91	72.36
Fri	3/30/2012+	17:00+	Sat+	3/31/2012+	03:00+	600	75.12	83.17
Sat	3/31/2012+	18:00+	Sun+	4/1/2012+	06:00+	720	78.41	22.50
Tue	4/3/2012+	17:00+	Wed+	4/4/2012+	05:00+	720	79.59	17.50
Wed	4/4/2012+	17:00+	Thu+	4/5/2012+	03:00+	600	76.75	60.83
						674.12	**76.11**	**50.60**

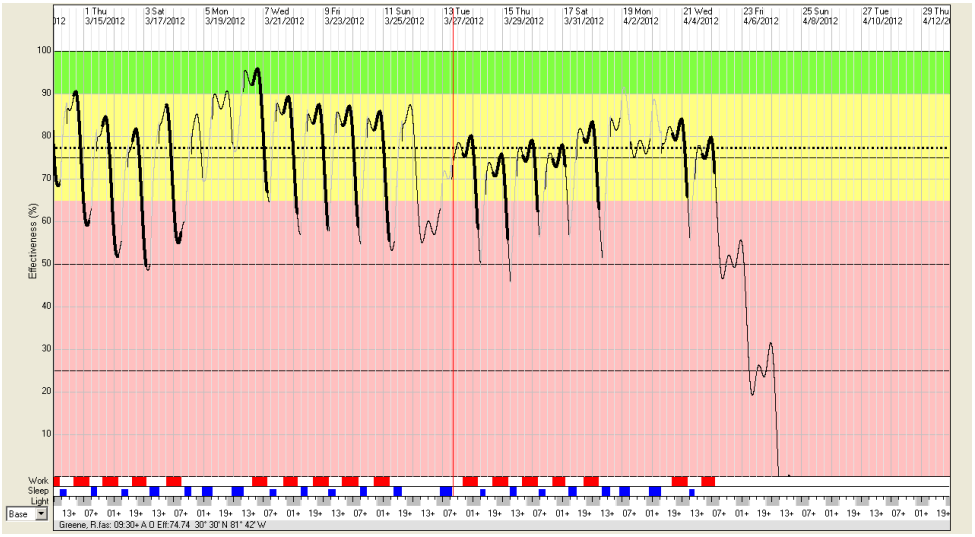

Figure 9.19 Effective analysis for schedule: J006 – Actual

This study participant worked an average of 674 minutes per day and spent about 50% of the time below critical cutoff level. This participant would have benefitted from fatigue countermeasures.

Table 9.20 J0009 – Actual (Night)

Day	Date	Time	Day	Date	Time	Dur	Eff	%BCL
Tue	11/29/2011+	18:00+	Wed+	11/30/2011+	07:00+	780	85.95	24.87
Wed	11/30/2011+	18:00+	Thu+	12/1/2011+	07:00+	780	87.69	18.97
Thu	12/1/2011+	18:00+	Fri+	12/2/2011+	07:00+	780	86.76	18.46
Mon	12/5/2011+	18:00+	Tue+	12/6/2011+	07:00+	780	90.96	11.67
Tue	12/6/2011+	18:00+	Wed+	12/7/2011+	07:00+	780	91.31	9.36
Wed	12/7/2011+	18:00+	Thu+	12/8/2011+	07:00+	780	89.86	9.62
Sat	12/10/2011+	18:00+	Sun+	12/11/2011+	07:00+	780	93.59	1.28
Sun	12/11/2011+	19:00+	Mon+	12/12/2011+	07:00+	720	93.52	0.00
Mon	12/12/2011+	18:00+	Tue+	12/13/2011+	07:00+	780	91.82	0.38
Tue	12/13/2011+	18:00+	Wed+	12/14/2011+	07:00+	780	93.00	0.00
Wed	12/14/2011+	18:00+	Thu+	12/15/2011+	07:00+	780	91.23	0.00
Thu	12/15/2011+	18:00+	Fri+	12/16/2011+	07:00+	780	90.23	0.13
						775.00.	**90.47.**	**7.95**

Figure 9.20 Effective analysis for schedule: J0009 – Actual (Night)

This study participant worked nights an average of 775 minutes per day but, with a three-day recovery period, only spent 7.95% of the time below critical cutoff levels. No other countermeasures needed.

Table 9.21 J0010 – Actual (Night)

Day	Date	Time	Day	Date	Time	Dur	Eff	%BCL
Mon	7/9/2012+	10:00+	Mon+	7/9/2012+	16:00+	360	71.18	100.00
Mon	7/9/2012+	18:00+	Tue+	7/10/2012+	11:00+	1020	62.98	75.39
Tue	7/10/2012+	20:00+	Wed+	7/11/2012+	11:00+	900	65.44	77.11
Wed	7/11/2012+	21:00+	Thu+	7/12/2012+	09:00+	720	68.15	72.78
Thu	7/12/2012+	20:00+	Fri+	7/13/2012+	10:00+	840	71.15	65.12
Fri	7/13/2012+	20:00+	Sat+	7/14/2012+	11:00+	900	67.93	69.00
Mon	7/16/2012+	20:00+	Tue+	7/17/2012+	12:00+	960	82.10	52.19
Tue	7/17/2012+	23:00+	Wed+	7/18/2012+	12:00+	780	77.93	63.21
Wed	7/18/2012+	20:00+	Thu+	7/19/2012+	09:00+	780	80.65	44.23
Thu	7/19/2012+	20:00+	Fri+	7/20/2012+	11:00+	900	76.94	52.22
Fri	7/20/2012+	23:00+	Sat+	7/21/2012+	10:00+	660	78.99	51.52
Mon	7/23/2012+	20:00+	Tue+	7/24/2012+	10:00+	840	84.04	35.60
Tue	7/24/2012+	20:00+	Wed+	7/25/2012+	10:00+	840	84.79	32.02
Wed	7/25/2012+	20:00+	Thu+	7/26/2012+	10:00+	840	85.24	28.33
Mon	7/30/2012+	21:00+	Tue+	7/31/2012+	10:00+	780	62.43	100.00
Tue	7/31/2012+	20:00+	Wed+	8/1/2012+	09:00+	780	73.50	47.95
Wed	8/1/2012+	20:00+	Thu+	8/2/2012+	09:00+	780	77.28	41.54
Thu	8/2/2012+	20:00+	Fri+	8/3/2012+	09:00+	780	77.71	39.10
						803.33.	**74.89.**	**57.07**

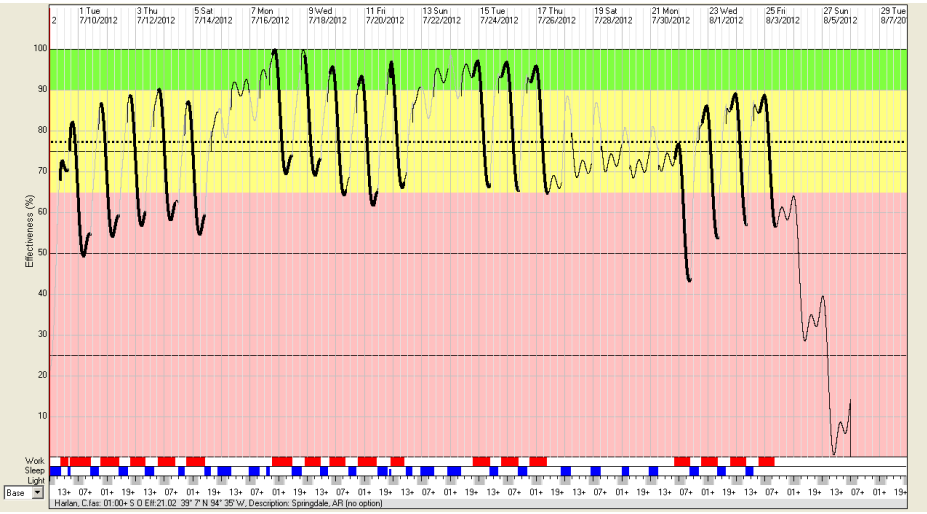

Figure 9.21 Effective analysis for schedule: J0010 – Actual (Night)

This study participant worked five consecutive days with two days off for an average of 803 minutes worked. With 2.5 days off, the average time below fatigue cutoff level dropped considerably.

Table 9.22 J0012 – Actual (Night)

Start			End			Stats		
Day	**Date**	**Time**	**Day**	**Date**	**Time**	**Dur**	**Eff**	**%BCL**
Tue	7/10/2012+	01:00+	Tue+	7/10/2012+	09:00+	480	74.76	68.96
Tue	7/10/2012+	20:00+	Wed+	7/11/2012+	10:00+	840	79.25	46.90
Wed	7/11/2012+	21:00+	Thu+	7/12/2012+	08:00+	660	80.49	38.64
Thu	7/12/2012+	20:00+	Fri+	7/13/2012+	09:00+	780	81.44	36.28
Fri	7/13/2012+	20:00+	Sat+	7/14/2012+	10:00+	840	81.27	37.50
Mon	7/16/2012+	20:00+	Tue+	7/17/2012+	11:00+	900	9.32	100.00
Wed	7/18/2012+	01:00+	Wed+	7/18/2012+	11:00+	600	37.60	100.00
Wed	7/18/2012+	21:00+	Thu+	7/19/2012+	10:00+	780	60.76	100.00
Thu	7/19/2012+	21:00+	Fri+	7/20/2012+	09:00+	720	68.65	100.00
Fri	7/20/2012+	23:00+	Sat+	7/21/2012+	10:00+	660	79.30	34.55
Mon	7/23/2012+	20:00+	Tue+	7/24/2012+	10:00+	840	83.43	25.95
Tue	7/24/2012+	20:00+	Wed+	7/25/2012+	09:00+	780	84.74	19.23
Wed	7/25/2012+	20:00+	Thu+	7/26/2012+	10:00+	840	83.45	22.86
Thu	7/26/2012+	21:00+	Fri+	7/27/2012+	12:00+	900	80.64	32.33
Fri	7/27/2012+	22:00+	Sat+	7/28/2012+	12:00+	840	80.44	32.62
Mon	7/30/2012+	21:00+	Tue+	7/31/2012+	10:00+	780	80.20	28.08
Tue	7/31/2012+	21:00+	Wed+	8/1/2012+	09:00+	720	86.40	15.00
Wed	8/1/2012+	20:00+	Thu+	8/2/2012+	09:00+	780	88.80	8.33
Thu	8/2/2012+	20:00+	Fri+	8/3/2012+	09:00+	780	88.37	6.79
Sun	8/5/2012+	21:00+	Mon+	8/6/2012+	09:00+	720	83.95	16.67
						762	**74.63**	**42.62**

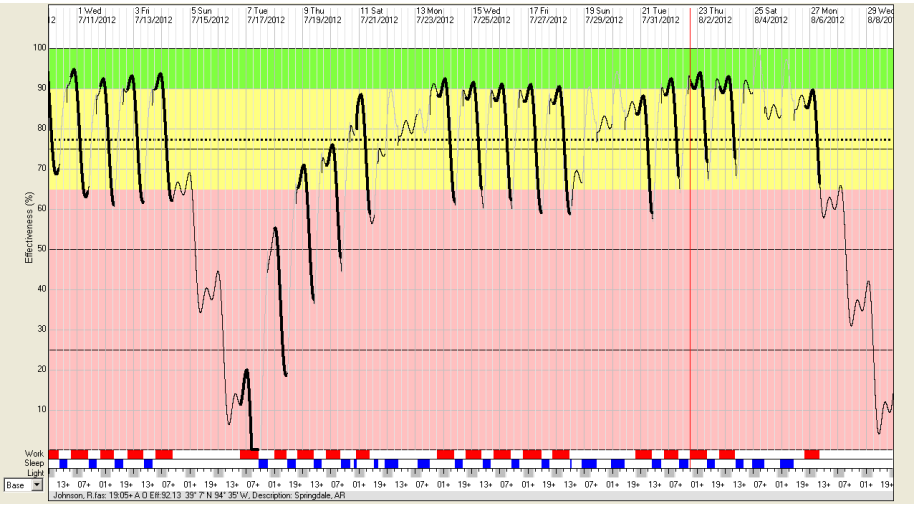

Figure 9.22 Effective analysis for schedule: J0012 – Actual (Night)

This participant worked midnights with very little sleep for two nights, but with three days off, returned to acceptable levels on the last four days of work cycle.

Table 9.23 J0012 – Actual (Night) – Edited

Edited to include sleep times on off days.

J0012 - Edited								
Start			End			Stats		
Day	Date	Time	Day	Date	Time	Dur	Eff	%BCL
Tue	7/10/2012+	01:00+	Tue+	7/10/2012+	09:00+	480	72.42	82.5
Tue	7/10/2012+	20:00+	Wed+	7/11/2012+	10:00+	840	77.2	54.29
Wed	7/11/2012+	21:00+	Thu+	7/12/2012+	08:00+	660	77.79	47.73
Thu	7/12/2012+	20:00+	Fri+	7/13/2012+	09:00+	780	79.04	44.23
Fri	7/13/2012+	20:00+	Sat+	7/14/2012+	10:00+	840	79.06	45
Mon	7/16/2012+	20:00+	Tue+	7/17/2012+	11:00+	900	88.2	33.67
Wed	7/18/2012+	01:00+	Wed+	7/18/2012+	11:00+	600	78.59	56.17
Wed	7/18/2012+	21:00+	Thu+	7/19/2012+	10:00+	780	84.29	35.9
Thu	7/19/2012+	21:00+	Fri+	7/20/2012+	09:00+	720	82.76	33.75
Fri	7/20/2012+	23:00+	Sat+	7/21/2012+	10:00+	660	80.58	41.82
Mon	7/23/2012+	20:00+	Tue+	7/24/2012+	10:00+	840	85.9	28.33
Tue	7/24/2012+	20:00+	Wed+	7/25/2012+	09:00+	780	85.14	25
Wed	7/25/2012+	20:00+	Thu+	7/26/2012+	10:00+	840	82.56	30
Thu	7/26/2012+	21:00+	Fri+	7/27/2012+	12:00+	900	78.88	40.11
Fri	7/27/2012+	22:00+	Sat+	7/28/2012+	12:00+	840	78.2	41.31
Mon	7/30/2012+	21:00+	Tue+	7/31/2012+	10:00+	780	81.26	32.56
Tue	7/31/2012+	21:00+	Wed+	8/1/2012+	09:00+	720	86.06	20
Wed	8/1/2012+	20:00+	Thu+	8/2/2012+	09:00+	780	88	13.33
Thu	8/2/2012+	20:00+	Fri+	8/3/2012+	09:00+	780	87.38	12.18
Sun	8/5/2012+	21:00+	Mon+	8/6/2012+	09:00+	720	84.69	19.44
						762	82.14	35.82

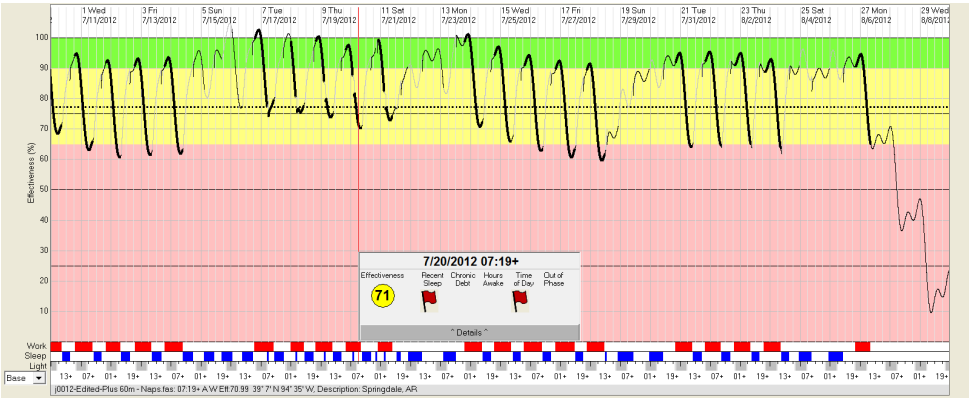

Figure 9.23 Effective analysis for schedule: J0012 – Actual (Night) – Edited

Table 9.24 J0012 – Actual (Night) – Edited – Plus Naps

j0012-Edited-Plus	60m Naps							
Start			End			Stats		
Day	Date	Time	Day	Date	Time	Dur	Eff	%BCL
Tue	7/10/2012+	01:00+	Tue+	7/10/2012+	09:00+	480	72.42	82.5
Tue	7/10/2012+	20:00+	Wed+	7/11/2012+	10:00+	840	77.2	54.29
Wed	7/11/2012+	21:00+	Thu+	7/12/2012+	08:00+	660	77.79	47.73
Thu	7/12/2012+	20:00+	Fri+	7/13/2012+	09:00+	780	79.04	44.23
Fri	7/13/2012+	20:00+	Sat+	7/14/2012+	10:00+	840	79.06	45
Mon	7/16/2012+	20:00+	Tue+	7/17/2012+	11:00+	900	89.42	17.89
Wed	7/18/2012+	01:00+	Wed+	7/18/2012+	11:00+	600	82.11	50
Wed	7/18/2012+	21:00+	Thu+	7/19/2012+	10:00+	780	87.22	29.62
Thu	7/19/2012+	21:00+	Fri+	7/20/2012+	09:00+	720	85.05	32.22
Fri	7/20/2012+	23:00+	Sat+	7/21/2012+	10:00+	660	82.97	48.18
Mon	7/23/2012+	20:00+	Tue+	7/24/2012+	10:00+	840	86.77	34.88
Tue	7/24/2012+	20:00+	Wed+	7/25/2012+	09:00+	780	84.39	34.1
Wed	7/25/2012+	20:00+	Thu+	7/26/2012+	10:00+	840	80.93	40.12
Thu	7/26/2012+	21:00+	Fri+	7/27/2012+	12:00+	900	76.65	50.78
Fri	7/27/2012+	22:00+	Sat+	7/28/2012+	12:00+	840	75.45	52.86
Mon	7/30/2012+	21:00+	Tue+	7/31/2012+	10:00+	780	82.09	38.21
Tue	7/31/2012+	21:00+	Wed+	8/1/2012+	09:00+	720	84.83	29.17
Wed	8/1/2012+	20:00+	Thu+	8/2/2012+	09:00+	780	85.96	23.59
Thu	8/2/2012+	20:00+	Fri+	8/3/2012+	09:00+	780	84.62	23.72
Sun	8/5/2012+	21:00+	Mon+	8/6/2012+	09:00+	720	85.55	24.58
						762	82.12	39.26

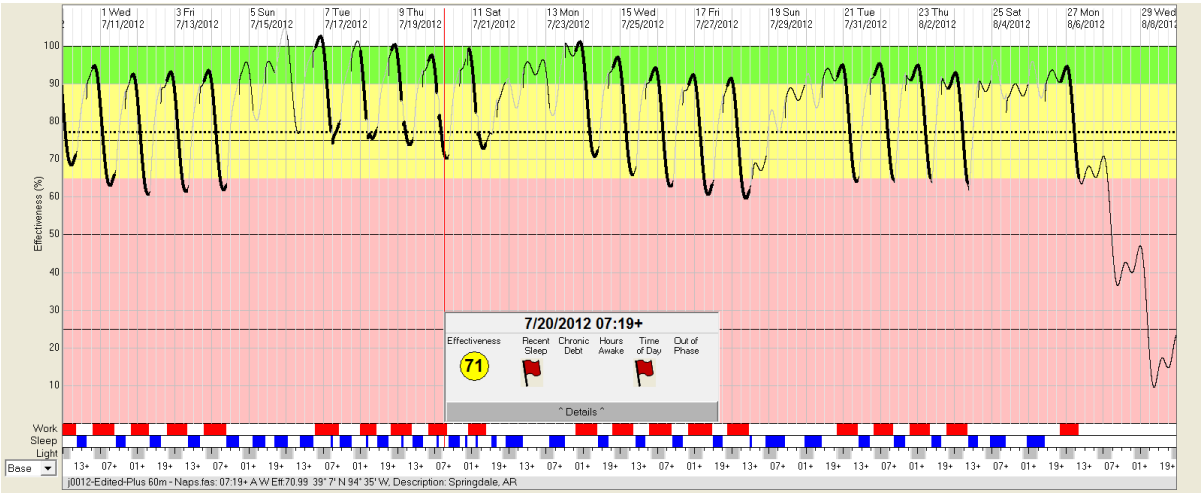

Figure 9.24 Effective analysis for schedule: J0012 – Actual (Night) – Edited – Plus Naps

Table 9.25 J0018 - Actual (Night)

Start			End			Stats		
Day	**Date**	**Time**	**Day**	**Date**	**Time**	**Dur**	**Eff**	**%BCL**
Mon	12/5/2011+	18:00+	Tue+	12/6/2011+	06:00+	720	94.40	5.83
Tue	12/6/2011+	18:00+	Wed+	12/7/2011+	06:00+	720	93.44	4.58
Wed	12/7/2011+	18:00+	Thu+	12/8/2011+	06:00+	720	93.37	2.36
Thu	12/8/2011+	14:00+	Fri+	12/9/2011+	02:00+	720	98.31	0.00
Fri	12/9/2011+	18:00+	Sat+	12/10/2011+	06:00+	720	94.54	0.00
Mon	12/12/2011+	19:00+	Tue+	12/13/2011+	06:00+	660	95.05	0.00
Tue	12/13/2011+	18:00+	Wed+	12/14/2011+	06:00+	720	94.77	0.00
Wed	12/14/2011+	18:00+	Thu+	12/15/2011+	07:00+	780	89.11	8.97
Thu	12/15/2011+	18:00+	Fri+	12/16/2011+	06:00+	720	90.47	0.00
Fri	12/16/2011+	19:00+	Sat+	12/17/2011+	06:00+	660	87.88	0.30
						714.00	**93.13**	**2.30**

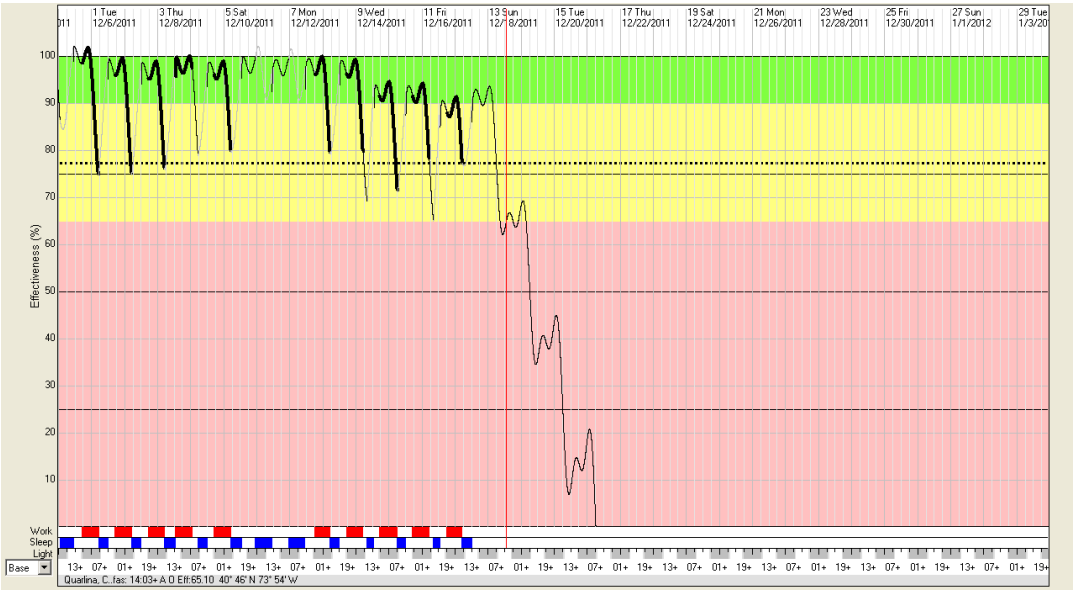

Figure 9.25 Effective analysis for schedule: J0018 - Actual (Night)

This study participant worked evenings and into the early morning hours, but only spent 2.3% of the time below critical cutoff level.

Table 9.26 J0019 - Actual (Night)

Start			End			Stats		
Day	**Date**	**Time**	**Day**	**Date**	**Time**	**Dur**	**Eff**	**%BCL**
Fri	4/13/2012+	10:00+	Fri+	4/13/2012+	21:00+	660	91.97	0.00
Sun	4/15/2012+	09:00+	Sun+	4/15/2012+	22:00+	780	90.39	0.00
Mon	4/16/2012+	19:00+	Tue+	4/17/2012+	05:00+	600	80.75	36.33
Fri	4/20/2012+	02:00+	Fri+	4/20/2012+	12:00+	600	73.06	82.83
Wed	4/25/2012+	23:00+	Thu+	4/26/2012+	12:00+	780	74.71	69.10
Fri	4/27/2012+	11:00+	Fri+	4/27/2012+	21:00+	600	86.31	0.00
Sun	4/29/2012+	22:00+	Mon+	4/30/2012+	09:00+	660	74.87	56.06
Wed	5/2/2012+	04:00+	Wed+	5/2/2012+	13:00+	540	67.07	100.00
Sat	5/5/2012+	11:00+	Sat+	5/5/2012+	23:00+	720	85.81	0.00
Mon	5/7/2012+	08:00+	Mon+	5/7/2012+	18:00+	600	85.74	0.00
Thu	5/10/2012+	18:00+	Fri+	5/11/2012+	03:00+	540	83.87	20.00
Sat	5/12/2012+	04:00+	Sat+	5/12/2012+	13:00+	540	64.49	100.00
Mon	5/14/2012+	08:00+	Mon+	5/14/2012+	19:00+	660	83.75	0.00
						636.92	**80.65**	33.96

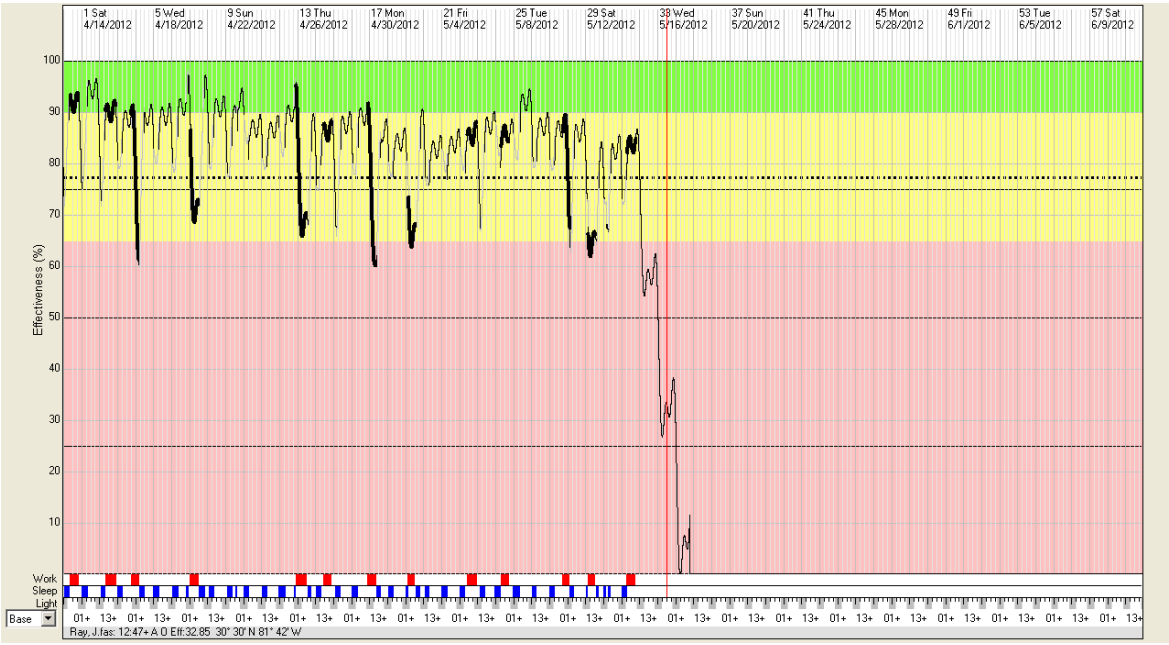

Figure 9.26 Effective analysis for schedule: J0019 - Actual (Night)

This study participant worked several long days, but spent only 33% of the time below critical cutoff level.

Table 9.27 J0020 - Actual (Night)

Start		End			Stats			
Day	**Date**	**Time**	**Day**	**Date**	**Time**	**Dur**	**Eff**	**%BCL**
Sun	6/3/2012	00:00	Sun	6/3/2012	11:00	660	71.11	100.00
Sun	6/3/2012	22:00	Mon	6/4/2012	09:00	660	62.29	100.00
Mon	6/4/2012	23:00	Tue	6/5/2012	12:00	780	62.85	100.00
Tue	6/5/2012	21:00	Wed	6/6/2012	10:00	780	62.31	100.00
Thu	6/7/2012	22:00	Fri	6/8/2012	12:00	840	43.30	100.00
Sun	6/10/2012	21:00	Mon	6/11/2012	07:00	600	57.69	100.00
Mon	6/11/2012	23:00	Tue	6/12/2012	08:00	540	70.18	100.00
Tue	6/12/2012	21:00	Wed	6/13/2012	08:00	660	71.95	100.00
Wed	6/13/2012	20:00	Thu	6/14/2012	10:00	840	67.15	100.00
Thu	6/14/2012	21:00	Fri	6/15/2012	04:00	420	67.62	100.00
Fri	6/15/2012	06:00	Fri	6/15/2012	13:00	420	75.55	86.90
Fri	6/15/2012	22:00	Sat	6/16/2012	13:00	900	50.08	100.00
Sun	6/17/2012	22:00	Mon	6/18/2012	11:00	780	0.10	100.00
Tue	6/19/2012	23:00	Wed	6/20/2012	09:00	600	61.56	100.00
						677	**57.03**	**99.42**

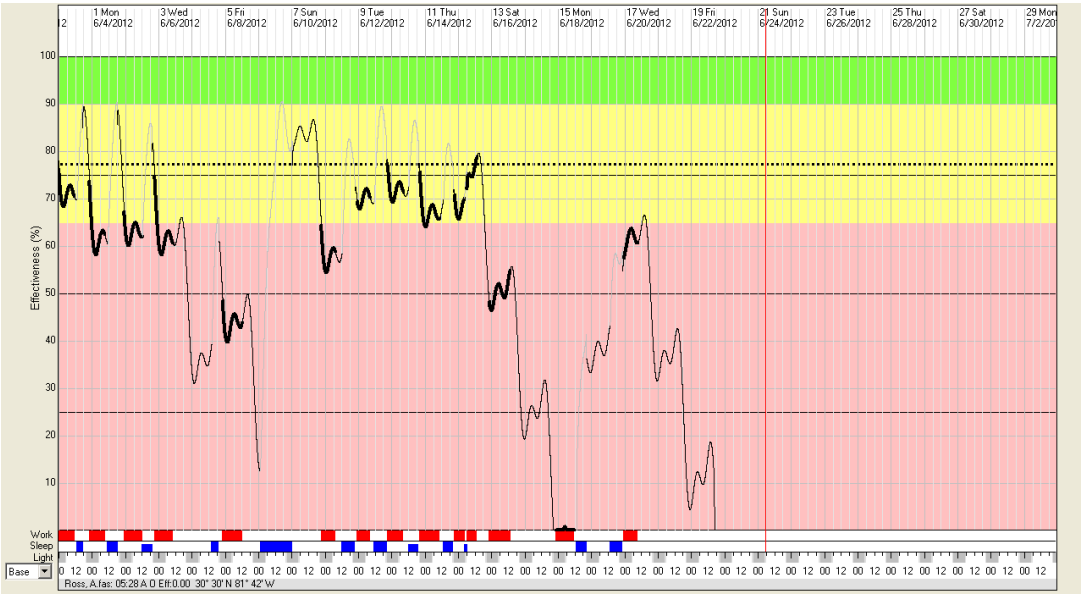

Figure 9.27 Effective analysis for schedule: J0020 - Actual (Night)

This study participant worked an average of 677 minutes per day with nearly 99% of the time working below critical cutoff levels. This schedule would be a candidate for fatigue countermeasures and, as shown in previous models, would return to acceptable level with naps.

Table 9.28 J0022 - Actual (Night)

Start			End			Stats		
Day	**Date**	**Time**	**Day**	**Date**	**Time**	**Dur**	**Eff**	**%BCL**
Mon	5/14/2012	19:00	Tue	5/15/2012	04:00	540	89.39	18.70
Tue	5/15/2012	19:00	Wed	5/16/2012	04:00	540	92.51	8.89
Wed	5/16/2012	19:00	Thu	5/17/2012	04:00	540	91.76	9.81
Thu	5/17/2012	19:00	Fri	5/18/2012	04:00	540	89.49	15.00
Fri	5/18/2012	19:00	Sat	5/19/2012	04:00	540	90.17	13.33
Mon	5/21/2012	19:00	Tue	5/22/2012	04:00	540	91.27	8.52
Tue	5/22/2012	19:00	Wed	5/23/2012	04:00	540	90.28	9.07
Wed	5/23/2012	19:00	Thu	5/24/2012	04:00	540	89.45	11.48
Thu	5/24/2012	19:00	Fri	5/25/2012	04:00	540	90.62	9.63
Fri	5/25/2012	19:00	Sat	5/26/2012	04:00	540	89.13	13.15
Tue	5/29/2012	19:00	Wed	5/30/2012	05:00	600	87.15	19.67
Wed	5/30/2012	19:00	Thu	5/31/2012	04:00	540	92.83	0.37
Thu	5/31/2012	19:00	Fri	6/1/2012	04:00	540	96.00	0.00
						544.62	**90.74**	**10.66**

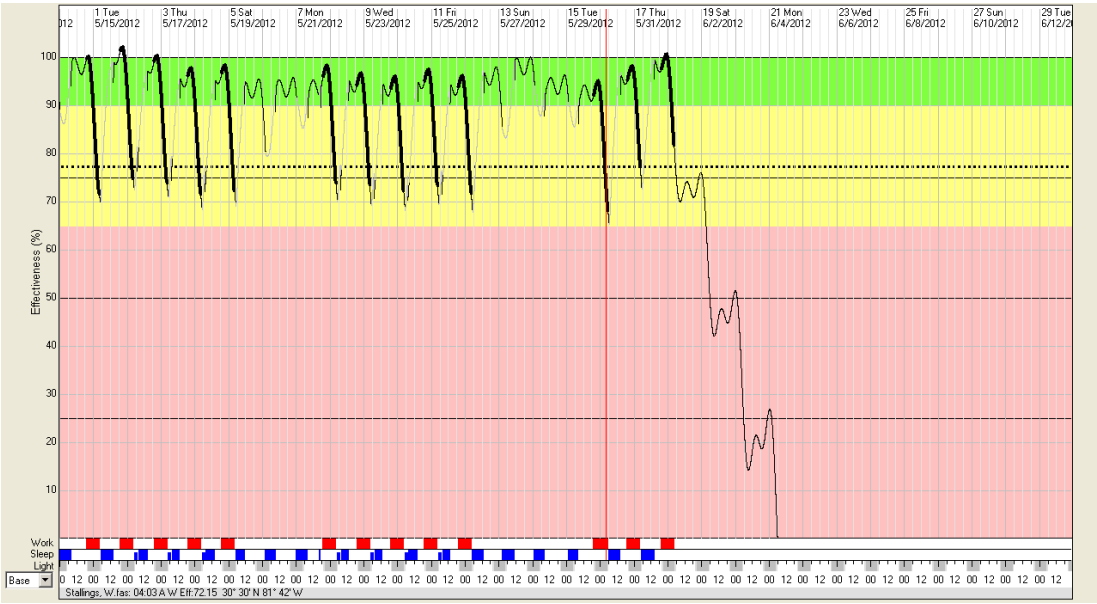

Figure 9.28 Effective analysis for schedule: J0022 - Actual (Night)

Evening shifts with only negligible time, 10.66%, below cutoff level.

Table 9.29 J0023 - Actual (Night)

Start			End			Stats		
Day	**Date**	**Time**	**Day**	**Date**	**Time**	**Dur**	**Eff**	**%BCL**
Mon	11/28/2011+	01:00+	Mon+	11/28/2011+	06:00+	300	79.01	46.67
Mon	11/28/2011+	18:00+	Tue+	11/29/2011+	06:00+	720	89.55	15.28
Tue	11/29/2011+	18:00+	Wed+	11/30/2011+	06:00+	720	91.97	7.50
Wed	11/30/2011+	18:00+	Thu+	12/1/2011+	06:00+	720	87.65	12.64
Thu	12/1/2011+	18:00+	Fri+	12/2/2011+	06:00+	720	93.77	0.28
Fri	12/2/2011+	18:00+	Sat+	12/3/2011+	06:00+	720	93.15	0.00
Sat	12/3/2011+	18:00+	Sun+	12/4/2011+	06:00+	720	95.09	0.00
Mon	12/5/2011+	18:00+	Tue+	12/6/2011+	06:00+	720	80.45	12.64
Tue	12/6/2011+	18:00+	Wed+	12/7/2011+	07:00+	780	82.90	11.67
Thu	12/8/2011+	18:00+	Fri+	12/9/2011+	06:00+	720	90.27	0.00
Fri	12/9/2011+	18:00+	Sat+	12/10/2011+	05:00+	660	92.22	0.00
						681.82	**89.20**	**7.72**

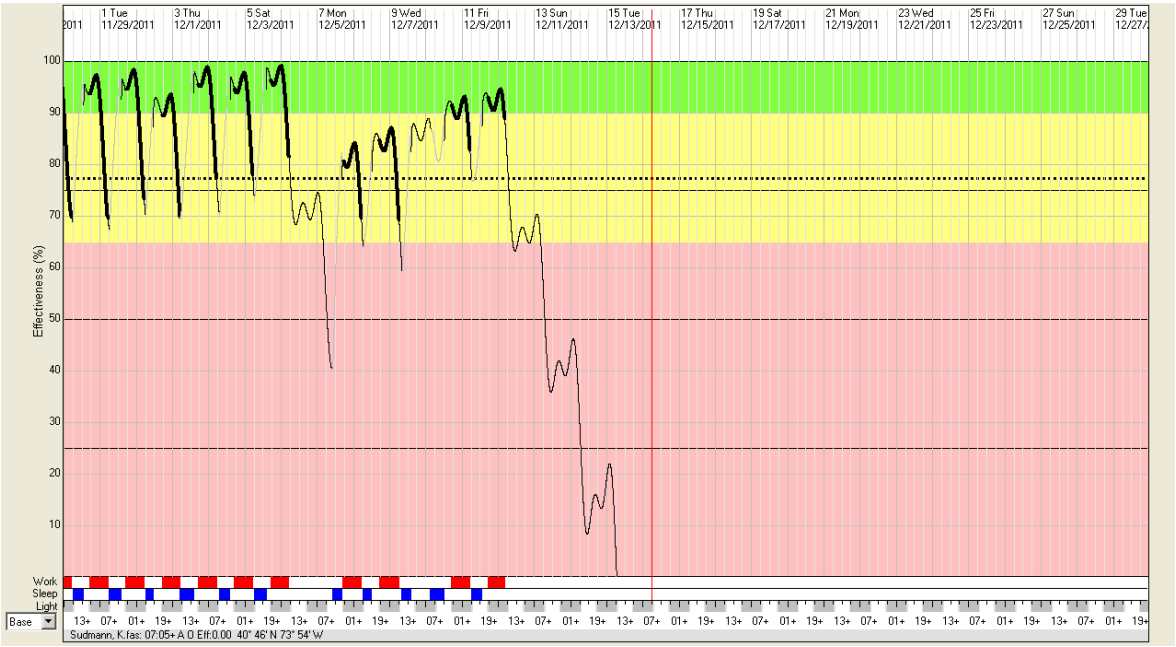

Figure 9.29 Effective analysis for schedule: J0023 - Actual (Night)

Interestingly, this study participant is within acceptable levels during his work shift even though he works at night on a 12-hour shift.

Table 9.30 J0024 - Actual (night)

Start			End			Stats		
Day	**Date**	**Time**	**Day**	**Date**	**Time**	**Dur**	**Eff**	**%BCL**
Thu	5/31/2012+	00:00+	Thu+	5/31/2012+	06:00+	360	73.82	70.56
Thu	5/31/2012+	17:00+	Fri+	6/1/2012+	05:00+	720	87.43	23.19
Fri	6/1/2012+	17:00+	Sat+	6/2/2012+	05:00+	720	86.24	22.78
Tue	6/5/2012+	15:00+	Wed+	6/6/2012+	05:00+	840	91.63	14.52
Wed	6/6/2012+	17:00+	Thu+	6/7/2012+	06:00+	780	88.74	21.92
Thu	6/7/2012+	17:00+	Fri+	6/8/2012+	05:00+	720	88.43	16.11
Fri	6/8/2012+	18:00+	Sat+	6/9/2012+	05:00+	660	89.25	13.48
Sat	6/9/2012+	18:00+	Sun+	6/10/2012+	06:00+	720	88.46	17.36
Tue	6/12/2012+	15:00+	Wed+	6/13/2012+	04:00+	780	93.05	0.00
Wed	6/13/2012+	17:00+	Thu+	6/14/2012+	05:00+	720	88.25	9.86
Thu	6/14/2012+	17:00+	Fri+	6/15/2012+	04:00+	660	89.93	0.00
Fri	6/15/2012+	17:00+	Sat+	6/16/2012+	06:00+	780	89.97	7.18
Sat	6/16/2012+	17:00+	Sun+	6/17/2012+	06:00+	780	89.31	6.03
Tue	6/19/2012+	17:00+	Wed+	6/20/2012+	05:00+	720	88.61	2.92
Wed	6/20/2012+	17:00+	Thu+	6/21/2012+	08:00+	900	84.89	21.33
Thu	6/21/2012+	17:00+	Fri+	6/22/2012+	05:00+	720	84.25	6.81
						723.75	**88.10**	**14.20**

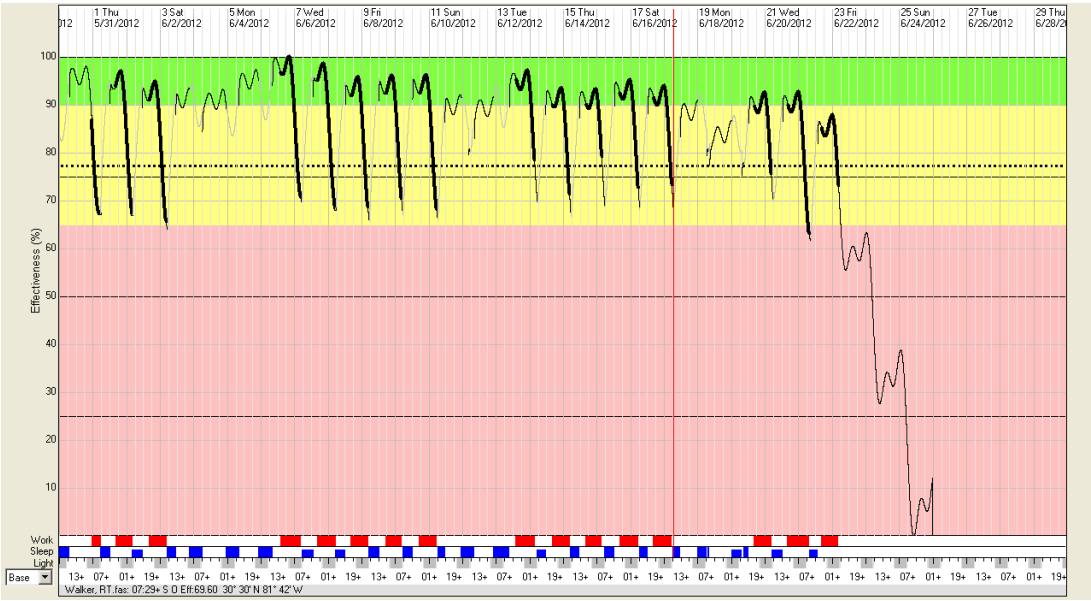

Figure 9.30 Effective analysis for schedule: J0024 - Actual (Night)

Table 9.31 J0025 – Actual (Night)

Start			End			Stats		
Day	**Date**	**Time**	**Day**	**Date**	**Time**	**Dur**	**Eff**	**%BCL**
Mon	4/23/2012+	23:00+	Tue+	4/24/2012+	07:00+	480	80.31	49.17
Wed	4/25/2012+	16:00+	Thu+	4/26/2012+	00:00+	480	99.01	0.00
Fri	4/27/2012+	10:00+	Fri+	4/27/2012+	20:00+	600	91.89	0.00
Sat	4/28/2012+	15:00+	Sun+	4/29/2012+	00:00+	540	95.21	0.00
Sun	4/29/2012+	16:00+	Mon+	4/30/2012+	00:00+	480	97.89	0.00
Thu	5/3/2012+	17:00+	Fri+	5/4/2012+	04:00+	660	93.67	2.88
Fri	5/4/2012+	17:00+	Sat+	5/5/2012+	05:00+	720	90.24	11.81
Sun	5/6/2012+	16:00+	Mon+	5/7/2012+	02:00+	600	93.85	0.00
Mon	5/7/2012+	23:00+	Tue+	5/8/2012+	11:00+	720	81.18	50.97
Wed	5/9/2012+	19:00+	Thu+	5/10/2012+	06:00+	660	87.31	16.82
Fri	5/11/2012+	13:00+	Fri+	5/11/2012+	22:00+	540	92.63	0.00
Sat	5/12/2012+	07:00+	Sat+	5/12/2012+	15:00+	480	84.62	0.00
Wed	5/16/2012+	09:00+	Wed+	5/16/2012+	20:00+	660	94.28	0.00
						586.15	**90.77**	**10.73**

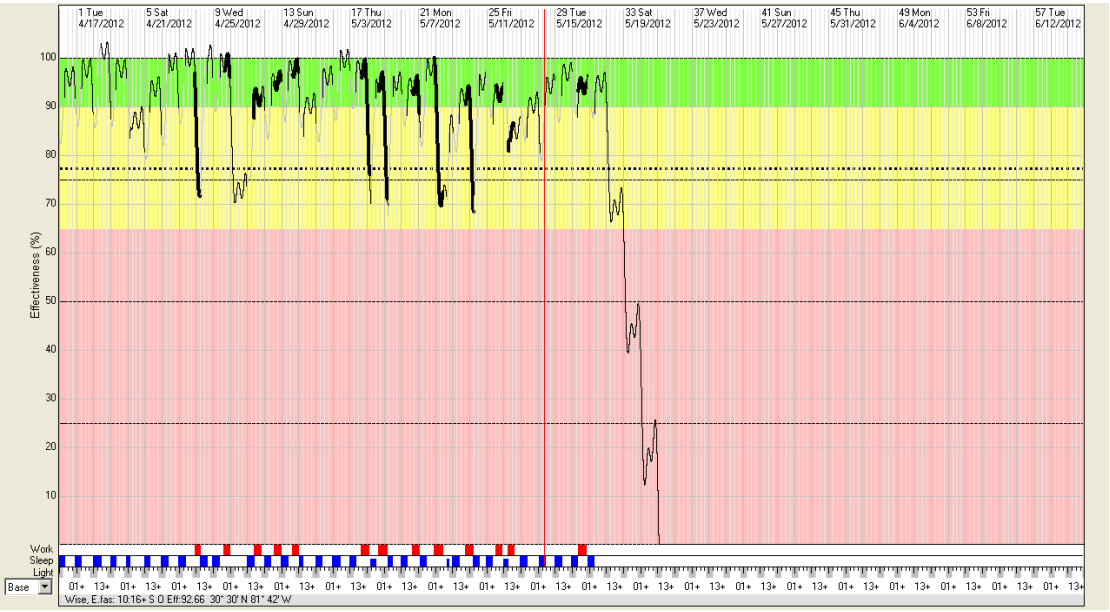

Figure 9.31 Effective analysis for schedule: J0025 - Actual (Night)

Table 9.32 J0026 - Actual (Night)

Start			End			Stats		
Day	**Date**	**Time**	**Day**	**Date**	**Time**	**Dur**	**Eff**	**%BCL**
Thu	7/12/2012+	01:00+	Thu+	7/12/2012+	14:00+	780	70.95	100.00
Fri	7/13/2012+	01:00+	Fri+	7/13/2012+	14:00+	780	70.05	100.00
Mon	7/16/2012+	01:00+	Mon+	7/16/2012+	14:00+	780	79.39	0.00
Tue	7/17/2012+	01:00+	Tue+	7/17/2012+	13:00+	720	73.04	100.00
Wed	7/18/2012+	01:00+	Wed+	7/18/2012+	14:00+	780	70.26	100.00
Thu	7/19/2012+	01:00+	Thu+	7/19/2012+	14:00+	780	70.72	100.00
Fri	7/20/2012+	01:00+	Fri+	7/20/2012+	12:00+	660	69.21	100.00
Mon	7/23/2012+	01:00+	Mon+	7/23/2012+	12:00+	660	78.87	20.61
Tue	7/24/2012+	01:00+	Tue+	7/24/2012+	13:00+	720	72.78	100.00
Wed	7/25/2012+	01:00+	Wed+	7/25/2012+	14:00+	780	76.54	71.15
Thu	7/26/2012+	01:00+	Thu+	7/26/2012+	14:00+	780	72.47	100.00
Fri	7/27/2012+	01:00+	Fri+	7/27/2012+	11:00+	600	72.66	100.00
Mon	7/30/2012+	02:00+	Mon+	7/30/2012+	15:00+	780	83.77	0.00
Tue	7/31/2012+	01:00+	Tue+	7/31/2012+	14:00+	780	74.05	100.00
Wed	8/1/2012+	02:00+	Wed+	8/1/2012+	14:00+	720	74.53	100.00
Thu	8/2/2012+	03:00+	Thu+	8/2/2012+	14:00+	660	76.82	66.06
						735.00	**74.14**	**78.46**

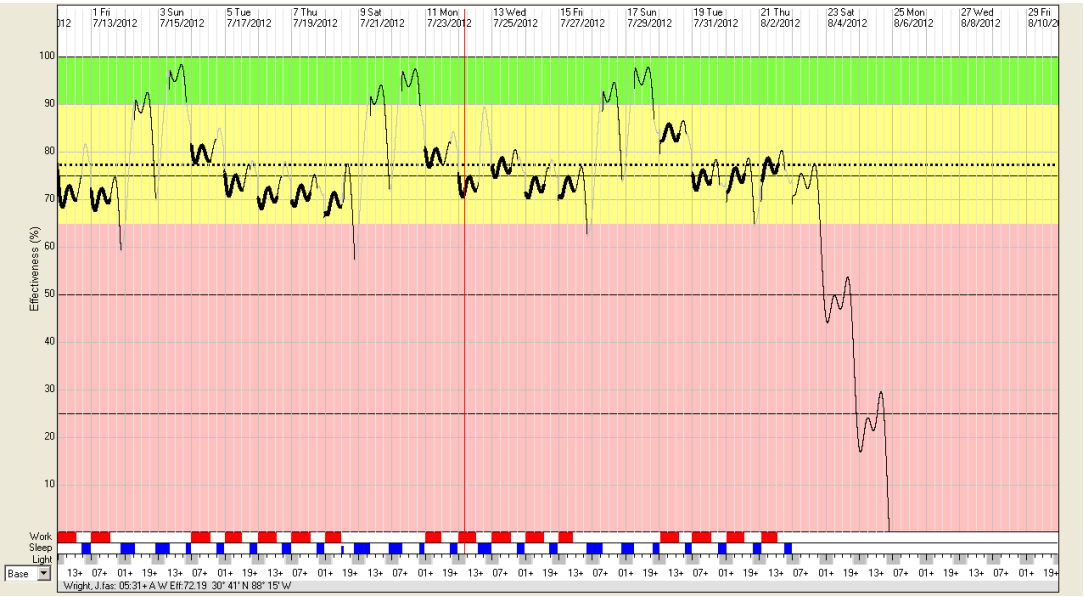

Figure 9.321 Effective analysis for schedule: J0026 - Actual (Night)

Appendix IV. Estimates of Impact of Fatigue Mitigation Efforts

Table 9.332 PHL 6 N 6hr slp no naps 1900-0500 - Work

PHL 6 N 6hr slp no naps 1900-0500.fas Work								
Start			**End**			**Stats**		
Day	**Date**	**Time**	**Day**	**Date**	**Time**	**Dur**	**Eff**	**%BCL**
Wed	5/1/2013	19:00	Thu	5/2/2013	05:00	600	80.08	30.33
Thu	5/2/2013	19:00	Fri	5/3/2013	05:00	600	77.63	35.50
Fri	5/3/2013	19:00	Sat	5/4/2013	05:00	600	77.09	35.33
Sat	5/4/2013	19:00	Sun	5/5/2013	05:00	600	77.09	34.00
Sun	5/5/2013	19:00	Mon	5/6/2013	05:00	600	77.39	31.83
Mon	5/6/2013	19:00	Tue	5/7/2013	05:00	600	77.88	29.33
Wed	5/8/2013	19:00	Thu	5/9/2013	05:00	600	79.13	23.50
Thu	5/9/2013	19:00	Fri	5/10/2013	05:00	600	79.81	20.17
Fri	5/10/2013	19:00	Sat	5/11/2013	05:00	600	80.51	16.83
Sat	5/11/2013	19:00	Sun	5/12/2013	05:00	600	81.20	13.33
Sun	5/12/2013	19:00	Mon	5/13/2013	05:00	600	81.89	9.67
Mon	5/13/2013	19:00	Tue	5/14/2013	05:00	600	87.47	0.00
Wed	5/15/2013	19:00	Thu	5/16/2013	05:00	600	85.75	0.00
Thu	5/16/2013	19:00	Fri	5/17/2013	05:00	600	85.88	0.00
Fri	5/17/2013	19:00	Sat	5/18/2013	05:00	600	86.18	0.00
Sat	5/18/2013	19:00	Sun	5/19/2013	05:00	600	86.58	0.00
Sun	5/19/2013	19:00	Mon	5/20/2013	05:00	600	87.04	0.00
						600.00	**81.68**	**16.46**

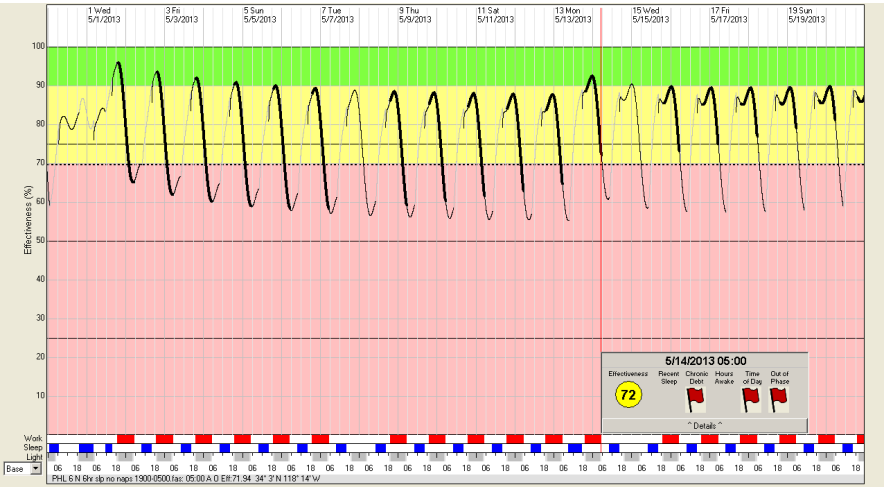

Figure 9.33 PHL 6 N 6hr slp no naps 1900-0500.fas-Work

Table 9.34 PHL 6 N 6hr slp 60m nap 1900-0500.fas - Work

Start			End			Stats		
Day	**Date**	**Time**	**Day**	**Date**	**Time**	**Dur**	**Eff**	**%BCL**
Wed	5/1/2013	19:00	Thu	5/2/2013	05:00	600	80.08	30.33
Thu	5/2/2013	19:00	Fri	5/3/2013	05:00	600	77.63	35.50
Fri	5/3/2013	19:00	Sat	5/4/2013	05:00	600	77.09	35.33
Sat	5/4/2013	19:00	Sun	5/5/2013	05:00	600	77.09	34.00
Sun	5/5/2013	19:00	Mon	5/6/2013	05:00	600	77.39	31.83
Mon	5/6/2013	19:00	Tue	5/7/2013	05:00	600	77.88	29.33
Wed	5/8/2013	19:00	Thu	5/9/2013	05:00	600	85.93	2.83
Thu	5/9/2013	19:00	Fri	5/10/2013	05:00	600	84.61	6.33
Fri	5/10/2013	19:00	Sat	5/11/2013	05:00	600	84.18	7.83
Sat	5/11/2013	19:00	Sun	5/12/2013	05:00	600	83.86	9.00
Sun	5/12/2013	19:00	Mon	5/13/2013	05:00	600	83.57	10.00
Mon	5/13/2013	19:00	Tue	5/14/2013	05:00	600	82.95	12.17
Wed	5/15/2013	19:00	Thu	5/16/2013	05:00	600	82.56	20.00
Thu	5/16/2013	19:00	Fri	5/17/2013	05:00	600	81.64	20.67
Fri	5/17/2013	19:00	Sat	5/18/2013	05:00	600	81.32	19.67
Sat	5/18/2013	19:00	Sun	5/19/2013	05:00	600	81.33	17.83
Sun	5/19/2013	19:00	Mon	5/20/2013	05:00	600	81.54	15.33
						600.00	**81.22**	**19.88**

Note: Average effectiveness level for days with counter measures implemented is ABOVE the cutoff of 70 and the percent time below criterion is within acceptable range.

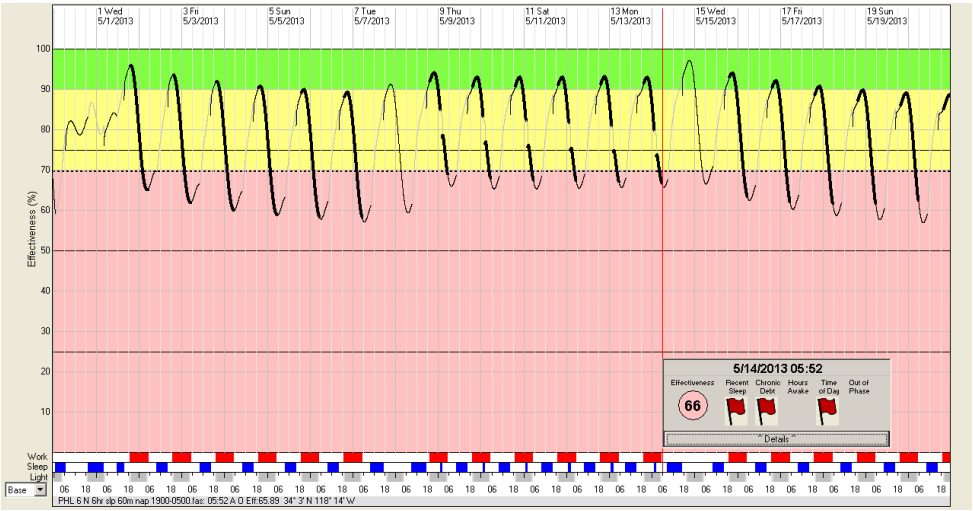

Figure 9.34 PHL 6 days 6 hr slp w 60 min nap 1900-0500

Table 9.353 PHL 6 N 6hr slp 90m nap 1900-0500a-Work

Start			End			Stats		
Day	**Date**	**Time**	**Day**	**Date**	**Time**	**Dur**	**Eff**	**%BCL**
Wed	5/1/2013	19:00	Thu	5/2/2013	05:00	600	80.08	30.33
Thu	5/2/2013	19:00	Fri	5/3/2013	05:00	600	77.63	35.50
Fri	5/3/2013	19:00	Sat	5/4/2013	05:00	600	77.09	35.33
Sat	5/4/2013	19:00	Sun	5/5/2013	05:00	600	77.09	34.00
Sun	5/5/2013	19:00	Mon	5/6/2013	05:00	600	77.39	31.83
Mon	5/6/2013	19:00	Tue	5/7/2013	05:00	600	77.88	29.33
Wed	5/8/2013	19:00	Thu	5/9/2013	05:00	600	86.39	0.00
Thu	5/9/2013	19:00	Fri	5/10/2013	05:00	600	86.02	0.00
Fri	5/10/2013	19:00	Sat	5/11/2013	05:00	600	86.06	0.00
Sat	5/11/2013	19:00	Sun	5/12/2013	05:00	600	86.05	0.00
Sun	5/12/2013	19:00	Mon	5/13/2013	05:00	600	85.99	0.00
Mon	5/13/2013	19:00	Tue	5/14/2013	05:00	600	85.57	0.00
Wed	5/15/2013	19:00	Thu	5/16/2013	05:00	600	87.94	3.67
Thu	5/16/2013	19:00	Fri	5/17/2013	05:00	600	84.71	13.33
Fri	5/17/2013	19:00	Sat	5/18/2013	05:00	600	83.44	14.83
Sat	5/18/2013	19:00	Sun	5/19/2013	05:00	600	82.88	14.17
Sun	5/19/2013	19:00	Mon	5/20/2013	05:00	600	82.71	12.50
						600.00	82.64	14.99

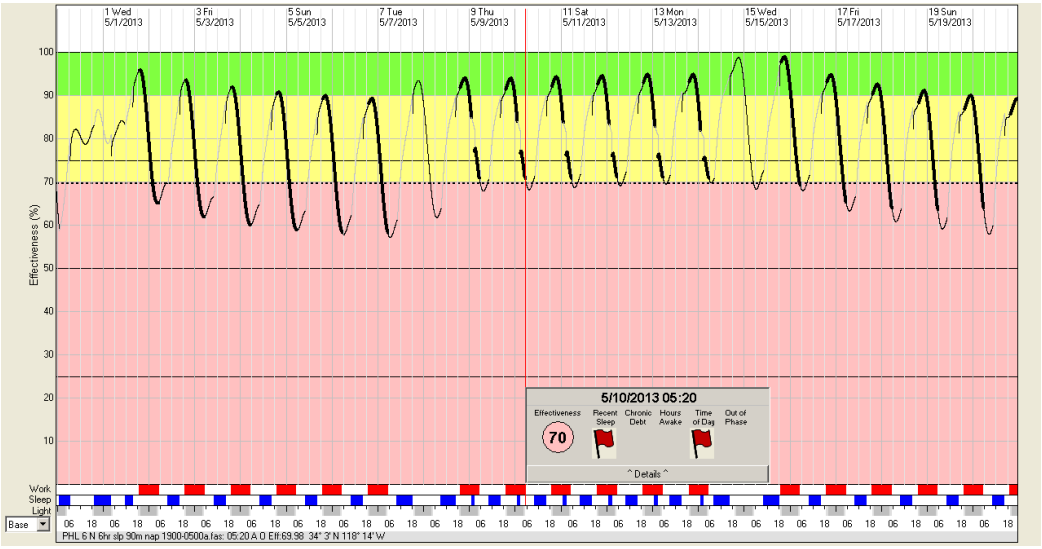

Figure 9.35 PHL 6 days 6 hr slp w 90 min nap 1900-0500a

Note: Average effectiveness level for days with counter measures implemented is ABOVE the cutoff of 70 and the percent time below criterion is within acceptable range.

Appendix V. Denver Fatigue Survey

Transportation Workers Health and Wellness Survey

Portions of this questionnaire have been developed as a result of a joint effort between the Unions and the University of Denver to assist in developing and understanding employee health and wellness. The results of this survey will be used to assist in better understanding and possibly developing a comprehensive wellness program for transportation employees. The goal being to improve work conditions and to make a better and safer work environment.

By completing this questionnaire, you indicate your willingness and consent to participate in this project. Your participation is completely voluntary and anonymous and may be discontinued at any time. Individual responses to this questionnaire will be held completely confidential. Responses will be analyzed only by the University of Denver. Final summary reports will present trends, percentages, and written responses to open-ended questions. No information that could identify an employee will be reported to any other party.

Please note that we have a CERTIFICATE OF CONFIDENTIALITY that is issued by the US Government that grants us immunity from disclosure of these data.

Please complete the attached questionnaire by circling the number which best indicates your answer. Please complete the ENTIRE questionnaire and turn it in before you leave.

Thank you for your assistance.

How likely are you to doze off or fall asleep in the following situation, in contrast to feeling just tired? This refers to your usual way of life. Even if you have not done some of these things recently, try to work out how they would have affected you. Use the following scale rate for each situation:

would *never* doze	*slight* chance of dozing	*moderate* chance of dozing	*high* chance of dozing
0	1	2	3

1.	Sitting and reading?	0 1 2 3
2.	Watching TV?	0 1 2 3
3.	Sitting, inactive in a public place (e.g. a theater or a meeting)?	0 1 2 3
4.	As a passenger in a car for an hour without a break?	0 1 2 3
5.	Lying down to rest in the afternoon when circumstances permit ?	0 1 2 3
6.	Sitting and talking to someone?	0 1 2 3
7.	Sitting quietly after a lunch without alcohol?	0 1 2 3
8.	In a car, while stopped for a few minutes in traffic?	0 1 2 3

The next NINE **questions relate to your usual sleep habits during the past month only.** Indicate the most accurate reply for the majority of days and nights in the past month.

During the past month				
9. What time do you usually go to bed?				
10. How long (in minutes) does it take you to fall asleep each night?				
11. When do you usually get up in the morning?				
12. On AVERAGE, how many hours of sleep do you get each night?				
13. How often have you had trouble sleeping because you...	Not during the past month	Less than once a week	Once or twice a week	Three or more times per week
a. Cannot fall asleep in 30 minutes				
b. Wake up during the night/early morning				
c. Have to get up to use the bathroom				
d. Cannot breathe comfortably				
e. Cough or snore loudly				
f. Feel too cold				
g. Feel too hot				
h. Have bad dreams				
i. Have pain				
j. Other reason(s), please describe and check - How Often…				
14. During the past month, how often have you taken MEDICINE prescribed or "over the counter") to help you sleep?				

15. During the past month, how often have you had TROUBLE STAYING AWAKE while driving, eating, or being social?				
16. During the past month, how much of a problem has it been for you to keep up ENTHUSIASM to get things done?				
17. During the past month, how would you rate your **SLEEP QUALITY** overall?	Very Good	Fairly Good	Fairly Bad	Very Bad

Use the scale below to respond to the following items:

1	2	3	4	5
To a Little or No Degree	To a Slight Degree	To a Moderate Degree	To a Considerable Degree	To a Very Great Degree

To What Degree ...(circle the number that corresponds to your answer....)

18. ... do you come to work fully rested and alert	**1 2 3 4 5**
19. ... do you feel supported by your supervisor	**1 2 3 4 5**
20. ... do you find it hard to concentrate on your job	**1 2 3 4 5**
21. … do you currently "nap" on the job	**1 2 3 4 5**
22. … do you think things need to change to improve fatigue	**1 2 3 4 5**
23. … does your family resent the hours you work	**1 2 3 4 5**
24. … has fatigue affected your job performance in the last week	**1 2 3 4 5**
25. … has the company addressed the fatigue issue satisfactorily	**1 2 3 4 5**
26. … have you been drowsy on the job in the last week	**1 2 3 4 5**
27. … have you been feeling bushed	**1 2 3 4 5**
28. … have you been feeling exhausted	**1 2 3 4 5**
29. … have you been feeling fatigued	**1 2 3 4 5**
30. … have you been feeling listless	**1 2 3 4 5**
31. … have you been feeling sluggish	**1 2 3 4 5**
32. … have you been feeling weary	**1 2 3 4 5**
33. … have you been feeling worn out	**1 2 3 4 5**
34. … have you found it difficult to stay awake on the job in the last week	**1 2 3 4 5**
35. … if you could find a job with comparable pay, would you quit this job	**1 2 3 4 5**
36. … do you support the current napping policy	**1 2 3 4 5**
37. … does your supervisor support a policy of "napping on the job"	**1 2 3 4 5**
38. … have you been feeling anxious or tense in the last week	**1 2 3 4 5**
39. … have you been feeling irritable	**1 2 3 4 5**
40. … have there been opportunities to "nap"	**1 2 3 4 5**
41. … did you experience "nodding off" during your last trip	**1 2 3 4 5**
42. … are you satisfied with your work schedule	**1 2 3 4 5**
43. ... are you less tired now than six months ago	**1 2 3 4 5**
44. .... has your fatigue level improved over the last month	**1 2 3 4 5**
45. ... are you more rested now than you were six months ago	**1 2 3 4 5**
46. … has your quality of life improved in the last month	**1 2 3 4 5**
to what degree have you been feeling ...	
47. … stress	**1 2 3 4 5**
48. … stressed out due to work	**1 2 3 4 5**
49. … stress due to uncertain start times	**1 2 3 4 5**

50. … overwhelmed by the job	**1 2 3 4 5**
51. … relaxed on the job	**1 2 3 4 5**
52. … very satisfied with this job	**1 2 3 4 5**
53. … thinking of quitting this job	**1 2 3 4 5**
54. … generally satisfied with the kind of work you do in this job	**1 2 3 4 5**
55. … most people on this job are very satisfied with the job	**1 2 3 4 5**
56. … people on this job often think of quitting	**1 2 3 4 5**
57. … I generally feel I have plenty of energy	**1 2 3 4 5**
58. … I usually feel drained	**1 2 3 4 5**
59. … I generally feel quite active	**1 2 3 4 5**
60. … I feel tired most of the time	**1 2 3 4 5**
61. … I generally feel full of vigor	**1 2 3 4 5**
62. … I usually feel rather lethargic	**1 2 3 4 5**
63. … I generally feel alert	**1 2 3 4 5**
64. … I often feel exhausted	**1 2 3 4 5**
65. … I usually feel lively	**1 2 3 4 5**
66. … I feel weary much of the time	**1 2 3 4 5**
67. … have you been able to concentrate on what you are doing	**1 2 3 4 5**
Health & Lifestyle Data	
68. On average, how many cigarettes do you smoke per week?	
69. On average, how many tins of tobacco do you use each week?	
70. On average, how many units of alcohol do you consume per week? (e.g. 1 unit = 1 beer or 1 glass of wine or 1 measure of spirit)	
71. How many cups of caffeinated coffee/ tea/cola do you consume each day?	
72. What is your current weight?	
73. What is your height?	
74. Do you think you are overweight?	Yes No
75. If yes, how many pounds are you over your ideal weight?	Yes No
76. Do you have trouble getting enough sleep?	Yes No
77. Do you snore?	Yes No
78. Has your spouse or partner complained of your snoring?	Yes No
79. Do you have high blood pressure?	Yes No
80. Are you on medication for high blood pressure?	Yes No
81. Do you have trouble FALLING asleep?	Yes No
82. Do you have trouble STAYING asleep?	Yes No
83. Has your snoring awakened your spouse/partner from sleep?	Yes No
84. Have you been diagnosed with a sleep disorder?	Yes No
85. Do you have sleep apnea?	Yes No
86. Have you been given a c-pap machine for your sleep apnea?	Yes No
87. Do you get regular exercise?	Yes No
88. Do you have a family history of diabetes?	Yes No
89. Have you been diagnosed with diabetes? (either type I or type II)	Yes No
90. Do you use INSULIN to control your diabetes?	Yes No
91. How many times a week do you exercise for 30 minutes or more?	

Please indicate whether you are: 92. coming ON (starting) a trip/shift _____ yes ____ no	
93. going OFF (ending) a trip/shift _____ yes ____ no	
94. When did you go on duty? _____ (e.g. 16:04 hours)	
95. What time is it now? _____ (e.g. 17:00 hours)	
96. How much sleep have you had in the last 24 hours? ____ (hours)	
97. How much sleep have you had in the last 72 hours? ____ (hours)	
98. How many times were you called unexpectedly in the last week?	
99. How many hours of sleep per day (24hr) did you average last week?	
100. How many trips/shifts have you worked in the last 24 hours?	
101. How many trips/shifts have you worked in the last 72 hours?	
102. How many naps did you take during your last trip/shift?	
103. How many naps did you take during your last 3 trips/shifts combined?	
104. How many minutes did you nap during your last trip?	

105. Circle the number below which indicates your current state of alertness:						
1	2	3	4	5	6	7
Fully alert	Very lively, responsive, not at peak	Okay, somewhat fresh	A little tired, less than fresh	Moderately let down	Extremely tired	Completely exhausted, unable to function

106. Circle the number below which indicates: How you felt during your last trip/shift:						
1	2	3	4	5	6	7
Fully alert	Very lively, responsive, not at peak	Okay, somewhat fresh	A little tired, less than fresh	Moderately let down	Extremely tired	Completely exhausted, unable to function

The following questions are related to your work.

1. About how many hours altogether did you work in the **past 7 days**? ____ (00-97)

Now please think of your work experience over the past 4 weeks (28 days). Indicate the number of days you spent in each of the following work situations.	**Number of days (00-28)**
2. Missed an entire work day because of problems with your physical or mental health (include only days missed for your own health)?	
3. Missed an entire work day for any other reason (including vacation)?	
4. Missed part of a work day because of problems with your physical or mental health (include only days missed for your own health)?	
5. Missed part of a work day for any other reason (including vacation)?	
6. Come in early, go home late, or work on your day off?	
7. About how many hours did you work in **the past 4 weeks (28 days)**?	

The next questions are about the time you spent during your hours at work in **the past 4 weeks (28 days)**. Using the following scales, circle the number that corresponds to your answer:

0	1	2	3	4
All of the time	Most of the time	Some of the time	A little of the time	None of the time

8. How often did health problems limit the kind or amount of work you could do?	0 1 2 3 4
9. How often was your performance higher than most workers on your job?	0 1 2 3 4
10. How often was your performance lower than most workers on your job?	0 1 2 3 4
11. How often did you do no work at times when you were supposed to be working?	0 1 2 3 4
12. How often did you find yourself not working as carefully as you should?	0 1 2 3 4
13. How often was the quality of your work lower than it should have been?	0 1 2 3 4
14. How often did you not concentrate enough on your work?	0 1 2 3 4

15. **On a scale from 0 to 10, how would you rate the usual performance of MOST WORKERS in a job similar to yours?**

Worst Performance										**Top Performance**
0	1	2	3	4	5	6	7	8	9	10

16. **How would you rate YOUR usual job performance over the <u>past year or two</u>?**

Worst Performance										**Top Performance**
0	1	2	3	4	5	6	7	8	9	10

17. **How would you rate YOUR <u>overall</u> job performance during the <u>past 4 weeks</u>?**

Worst Performance										**Top Performance**
0	1	2	3	4	5	6	7	8	9	10

18. **How would you <u>compare</u> your overall job performance on the days you worked during the past 4 weeks (28 days) with the performance of most other workers who have a similar type of job?**

0	1	2	3	4	5	6
A lot better	Somewhat Better	A little better	Average	A little worse	Somewhat worse	A lot Worse

What Days and Times have you worked in the LAST TWO WEEKS?
Use Military Time (e.g. 13:30)

Week One

	M	T	W	TH	F	S	S
START TIME							
END TIME							

Week Two

	M	T	W	TH	F	S	S
START TIME							
END TIME							

Demographic Information

These questions help us determine general characteristics of the people who respond to the questions.

19. Please circle your Gender: MALE FEMALE
20. Please circle your Race:

American Indian	Asian	Black	Hispanic or Latino	White	Other

21. Number of years of Education (e.g. High school = 12 years): _____
22. How old are you (e.g. 35 yrs, 4 months): _____
23. Please circle your Marital Status:

Single	Married	Divorced	In a Relationship

24. If you have been injured at work, whether you reported it or not, how many work related injuries have you had in the last four years (circle your response)?

0	1	2	3	4	5	6+

25. Length of time with railroad (e.g. 2 yrs, 3 months): _____.
26. Please indicate your job title: Engineer Conductor Other (circle).
27. Please describe the job you are currently on _____.
28. Length of time in your present title (e.g. 2 yrs, 3 months): _____?
29. Is this an assigned job (please circle)? Yes No
30. What pool or direction (please circle)?
31. Specify your job assignment (e.g. SB001): _____

North	South	East	West	Other:____

32. How many days do you usually work a month? _____.
33. What time did you start work today? _____.
34. About what time do you quit today? _____.
35. Which line do you most frequently work? _____.
36. Are you on the extraboard (please circle)? Yes No
37. How long (on average) does it take for you to commute to work? _____.

As you can see we are interested in safety, health, satisfaction and wellness. Please make a few suggestions as to what improvements could be made in these areas. Try to make practical suggestions that can be carried forward.

Please write any additional comments you have or share them with the research team on site.

Again, no identifying information will be shared with
anyone outside the University of Denver Research Team!

This is an **Anonymous** survey BUT it would really HELP if we could follow up with you in SIX months and we would also like to give you a copy of the final report, please give us your **NAME, Phone, and Email** address:

Name: (Optional): _____ (print)
Phone: (Optional): _____
Email Address: _____ @ _____ . _____

Remember: Only averages and percentages will be reported.
No identifying information will be released!

Thank you for your assistance!!!

Appendix VI. Denver Sleep Diary

Denver

Railroad Sleep Diary

Fatigue Study

Instructions

Participation in this study is voluntary. Information gathered from this sleep diary will be kept confidential. We have a certificate of confidentiality from the National Institute of Health which grants us immunity from subpoena and prosecution should we be asked to submit these documents. Only your written permission can authorize the release of the identifying information and data.

Please return the Sleep Diary on_____!!!

Persons who successfully complete the sleep diaries will receive a gift certificate to a local merchant.

Please do not hesitate to call if you have questions 303-871-2495

In order to give you your gift certificate we need:

First Name: _____ Last Name:_____ (print)
Address: _____
City: _____ State: _____ Zip: _____
Company you work for: _____
Phone: (_ _ _) _ _ _ - _ _ _ _ (h) and (_ _ _) _ _ _ - _ _ _ _ (m)

Email Address: _____ @ _____. _____
(print clearly & legibly in BLOCK letters)

If you have questions please write or call:

Patrick Sherry, PhD
National Center for Intermodal Transportation
University of Denver
2400 S. Gaylord
Denver, Colorado 80208
303-871-2495
psherry@du.edu

Remember: Only averages and percentages will be reported.
No identifying information will be released!

Thank you for your assistance!!!

INSTRUCTIONS for Completing the Sleep Diary:

1. *Please Indicate **HOW MUCH YOU SLEPT** each day and the times you slept by recording an S, W, or N in Column ONE.*
2. *Please indicate **HOW SLEEPY** you were during your waking hours by putting a number from 1 to 7 (where 7= very sleepy) in Column TWO.*
3. *Please indicate **HOW MUCH STRESS** you experienced by placing a number from 1 to 5 (where 5= Severe Stress) in Column THREE.*
4. *Please indicate HOW **DIFFICULT IT WAS TO FALL ASLEEP** by placing a number from 1 to 5 (where 5= Very Difficult to Fall Asleep) in Column FOUR.*
5. *Please indicate **YOUR SLEEP QUALITY** by placing a number from 1 to 5 (where 5= Very Poor Sleep Quality) in Column FIVE.*
6. *Please indicate **HOW MUCH CAFFEINE** or other alertness enhancing substances you consumed by placing a number indicating the number of units (e.g. one cup, two bottles, etc.) in Column SIX.*

EXAMPLE PAGE

	Sleep Wake	How Sleepy	How Stress	Diff to Sleep	Sleep Quality	# Caffeine		Month/Day:_____/_____
0:01	sho				1		**Sleep/Wake Sleep Activity Code**	**CAFÉ=Caffeine Use**
1:00	sho				1			
2:00	sho				1		SHO=sleep at home	Estimate # of cups or beverages (e.g. Coffee, energy drinks, cola, tea,
3:00	sho				1		W=working - awake	
4:00	sho				1		P = awake personal time	
5:00	sho				3		SAW= sleep at work	
6:00	w	1	3				N=NAP	
7:00	w	1	3					**Stress & DIFF**
8:00	w	1	3			2		**DIFF=Difficulty Falling Asleep**
9:00	w	2	4				**Sleepiness Rating**	
10:00	w	2	4				1.Extremely alert	1=None
11:00	w	3	4				2.Very alert	2=Minimal
12:00	w	3	3				3.Alert	3=Mild
13:00	Nap	5	3				4.Rather alert	4=Moderate
14:00	Nap	5	3				5.Neither alert nor sleepy	5=Severe
15:00	W	5	4			2	6.Some signs of sleepiness	
16:00	W	6	3			2	7.Sleepy, no effort to stay awake	**Sleep Quality**
17:00	p	6	2				8.Sleepy, effort to stay awake	1=Very Good
18:00	p	7	2				9.Very sleepy, great effort to	2=Good
19:00	p	7	1				keep awake, fighting sleep	3=Neutral
20:00	p	8	1	1				4= Poor
21:00	p	8	1	1				5=Very Poor
22:00	Sho	S	1			1		
23:00	Sho	S	1			1		

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4:00							P = awake personal time	energy drinks, cola, tea,
5:00							SAW= sleep at work	
6:00							N=NAP	
7:00								**Stress & DIFF**
8:00								**DIFF=Difficulty**
9:00							**Sleepiness Rating**	**Falling Asleep**
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23:00								

Additional Background Questions:

1. Do you take regular prescribed medications? Yes ___ No ____
2. For what medical condition? _____
3. What medications do you take? _____
4. What is your weight? _____
5. What is your height? _____
6. Do you have a sleep disorder? Yes ___ No ____ specify: _____
7. Please make any other comments:

_____
_____
_____

Please return the Sleep Diary via FEDEX to Research Team!!!

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Address: _____
City: _____ State: _____ Zip: _____
Company you work for: _____
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