Guide to Identifying and Reducing Workforce Fatigue in Rapid Renewal Projects

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SHRP 2

STRATEGIC HIGHWAY RESEARCH PROGRAM

Accelerating solutions for highway safety, renewal, reliability, and capacity

Guide to Identifying and Reducing Workforce Fatigue in Rapid Renewal Projects

S2-R03-RR-2

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THE SECOND STRATEGIC HIGHWAY RESEARCH PROGRAM

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TRANSPORTATION RESEARCH BOARD

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The research reported on herein was performed by Battelle, supported by EBL Consulting, Washington State University, The Minor Group, and Anderson Consulting. Thomas Sanquist, Battelle, was the principal investigator. The other authors of this report are J. Elizabeth Jackson, John L. Campbell, and Marvin McCallum, Battelle; E. B. Lee, EBL Consulting; and Hans P. A. Van Dongen and Peter McCauley, Washington State University. The authors acknowledge the contributions to this research from Glenna Redmond-Wolf, Jean Busto, and Diane Williams, Battelle; Melinda Jackson, Washington State University; Hollis Minor, The Minor Group; and Stuart Anderson, Anderson Consulting.

FOREWORD

Jerry A. DiMaggio
D.GE, PE, SHRP 2 Senior Program Officer, Renewal

This guide, *Guide to Identifying and Reducing Workforce Fatigue in Rapid Renewal Projects*, describes a 3-year research project and results performed as SHRP 2 Project R03. The research scope involved studying factors associated with workforce fatigue and stress in the rapid renewal environment and the risks to worker safety and construction productivity. The study team developed an integrated fatigue management toolkit, including work scheduling and work practice guidance based on fatigue models, organizational practice guidance, fatigue management reference material, and training materials for managers and workers. This suite of products was prepared with the goal of integrating applicable components into existing safety management systems for highway projects, thereby reducing fatigue risk and increasing safety.

Worker and manager fatigue is a problem on highway construction projects and is exacerbated by the rapid renewal or accelerated construction practices that involve longer shifts, night work, and weekend closures. This problem is widely acknowledged by both management and labor, although current methods that address fatigue tend to be informal and are widely variable. Working conditions associated with rapid renewal approaches include conducting work during off-peak hours, continuous weekend construction, extended nighttime operations, and conducting work in zones adjacent to traffic. Fatigue countermeasures and their effectiveness have been studied extensively and are already practiced in other industries. Countermeasures include strategic management interventions (e.g., fatigue training, work scheduling aids, incident reporting) as well as individual interventions (e.g., sleep hygiene, napping, appropriate use of caffeine, self-monitoring, and peer-monitoring).

A comprehensive description of factors contributing to workforce fatigue and stress in the rapid renewal environment was developed as part of this study. These factors were examined in a range of scenarios and in the ways in which different segments of the highway construction workforce are affected.

An integrated set of workforce fatigue risk factor definitions, fatigue risk management practices and techniques, and specific tools and procedures was developed into a toolkit that can be applied to comprehensively manage workforce fatigue. This toolkit complements the broader efforts of rapid renewal performance specifications, rapid renewal risk management, and rapid renewal project management. Training and outreach materials were also produced to support future workforce fatigue management efforts in the highway construction industry. Finally, an implementation strategy was prepared that identifies recommended activities to increase awareness of the potential risks and costs associated with workforce fatigue and stress, and to foster and reward industry members in adopting practices that manage these risks and costs.

CONTENTS

Online version of this report:
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1 INTRODUCTION

BACKGROUND

As America's highway infrastructure continues to age and congestion becomes an increasing concern, roadways must be renewed quickly, with minimal disruption to the community. Performing the complex, dynamic, and fast-paced work of street, road, and highway rapid renewal construction is dangerous work. On any construction site, the risk of potential injury or death is higher than for most other occupational groups. Construction workers are three times more likely than average to have an injury that requires time away from work. For those working extended shifts, night and evening shifts, and weekly overtime, the possibility of occupational injury is greater yet.

Rapid renewal practices include conducting work during off-peak hours, scheduling continuous weekend construction and extended nighttime operations, and conducting work in zones adjacent to traffic. While these strategies improve schedule performance, the associated conditions increase worker fatigue and stress, resulting in reduced levels of workforce safety and construction productivity. Shift workers are particularly prone to fatigue-related injuries if they work night shift, extended shifts (10 or more hours), or weeks longer than 40 h. Rapid renewal highway construction will increase over the next 10-year period, engaging 25,000 to 29,000 workers and managers in this work with increased risk for fatigue.

A variety of common construction scheduling approaches increase the risk for fatigue, including

- Extended workday: 8+ h;
- 48- to 55-h workweeks;
- Double shifts;
- Changes in shift to night work in the middle of week;

- Night work;
- Long-term night shifts;
- Weekend work;
- Extended weekend work: 33-h to 55-h closures; and
- Operations in close proximity to traffic.

It is clear that the steps necessary to prevent and manage fatigue vary from one workplace to the next, depending on the nature of the work, environmental conditions, and individual factors. That is, no single measure or intervention is likely to solve the problem. Therefore, the best way to minimize worker fatigue in operational settings is to follow an integrated risk management approach. A combination of work schedule management, training and education, schedule risk assessment, healthy sleep, and fatigue countermeasures has been proven in other industries to lead to a fundamental change in culture and philosophy regarding fatigue, both at the worker and management level.

The second Strategic Highway Research Program (SHRP 2) project developed fatigue risk management strategies and tools designed for all levels of rapid renewal highway construction organization, including employees and field supervision and project management personnel, to understand, manage, and reduce workforce fatigue risks to worker safety and construction productivity. This work was carried out by the Battelle-led team in the SHRP 2 R03 project, Identifying and Reducing Workforce Fatigue in Rapid Renewal Projects, and a separate technical report has been produced describing the methods and findings of that work.

MAIN STRATEGIES IDENTIFIED FOR SUCCESSFUL FATIGUE MANAGEMENT

- Build awareness of risk factors and motivation to mitigate, directed at the industry sector level, within state Departments of Transportation (DOTs), and with individual contractors;
- Assess risk factors for specific project operations that address a broad range of scenarios for worker scheduling;
- Train workers and managers to ensure an understanding of the nature of sleep loss, circadian rhythm, fatigue, and related performance impacts, as well as key elements of both preventive and operational approaches to reducing fatigue;
- Establish methods of monitoring and assessing risk factors and countermeasures to determine what is working well; and
- Provide fatigue-proofing strategies for specific operations to reduce the likelihood that a fatigue-related error will cause an accident or injury.

This guide includes specific sections that will allow users to develop and implement fatigue risk management. The guide consists of three sections:

1. **Organizational Practices Guidance:** Selected organizational practices that influence the adoption and successful implementation of fatigue risk management, including

- Assessing the corporate approach to fatigue risk management;
- Building fatigue management into the operation;
- Dispelling erroneous beliefs about fatigue;
- Analyzing fatigue risk trajectories;
- Assessing specific schedule risks;
- Formalizing the risk assessment process;
- Implementing fatigue countermeasures; and
- Reporting, investigation, and evaluation.

2. **Technical Reference Material:** An archival set of materials for more detailed reference by end-user organizations and individuals. It includes the following:

- *Sleep Basics*: Reference material concerning the biological mechanisms underlying sleep and fatigue.
- *Individual Countermeasures*: These fall into two main groups. One group of countermeasures is applied in the field and focused on alleviating the effects of fatigue, and the other is applied proactively, either as part of a regular sleep maintenance plan or whenever unusually fatiguing schedules are anticipated.
- *Organizational Countermeasures*: Fatigue-proofing practices (reducing the likelihood that a fatigue-related error will cause an accident or injury) applied at the organizational level and consisting of strategies and techniques that include elements of scheduling, fatigue training, and tools for identifying and evaluating fatigue-related performance impacts.

3. **Fatigue Risk Management Schedule Guidance and Work Practices:** A set of guides that can be used for rapid renewal project planning and fatigue risk assessment and mitigation across a range of scenario types and workforce segments.

Users of this guide should consult the specific sections on an as-needed basis, depending on the state of fatigue management within their organization. Further detail on this guide's contents can be found in the companion technical report for the R03 project, *Identifying and Reducing Workforce Fatigue in Rapid Renewal Projects*.

2 ORGANIZATIONAL PRACTICES GUIDANCE

This section describes adaptations of organizational practices for fatigue risk management that are more appropriate for an industry with considerable operational diversity, such as highway construction, with a focus on monitoring and mitigation. The approaches described in this section are meant to be flexible and adaptive so that they can apply to a broad range of organizational size and complexity.

Figure 2.1 illustrates the elements of organizational practice to address and implement fatigue risk management in highway construction firms (i.e., contractors). These practices would also be applicable to state employees if they are not already covered by work-hour limitations in labor agreements. The upper part of the figure lists general processes for fatigue risk management, and the bottom part lists specific implementation means to institutionalize those processes. The following sections discuss each of these process and implementation steps.

ASSESS CORPORATE APPROACH

The first process step in addressing fatigue risk management in highway construction is identifying the current corporate approach. The most fundamental question is whether an approach to fatigue management exists. Most of the time fatigue issues, if they are addressed at all, revolve around proper hydration and physical rest breaks in extremely hot weather, leaving fatigue from sleep loss and circadian rhythm misalignment (due to night work) unaddressed.

An enabling process for fatigue risk management is a corporate safety management system (SMS). It is likely that national-level construction firms have such systems in place, whereas smaller and regionalized firms may have more informal approaches. In either case, it is important to assess the extent to which fatigue risk management is or is not addressed. If an SMS exists, it can be reviewed for any mention of fatigue risks

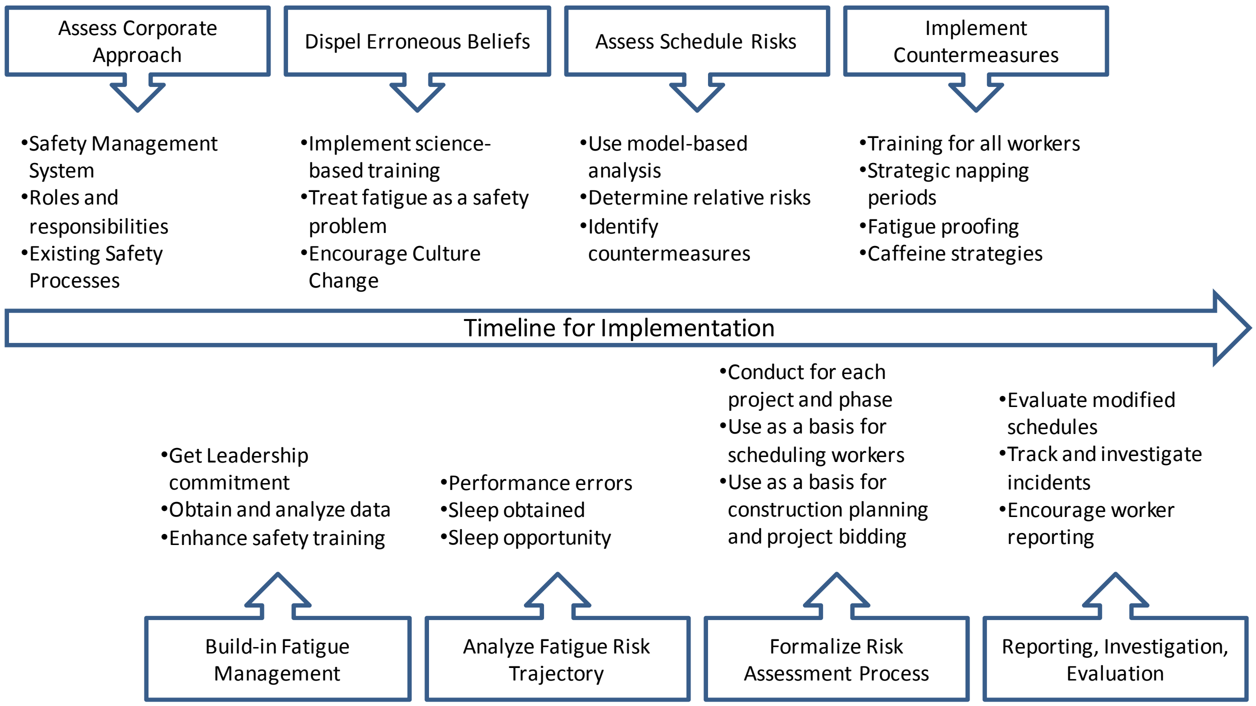

Figure 2.1. *Organizational practices for implementing fatigue risk management in highway construction firms.*

and mitigations and for appropriate places in which management processes might be inserted to address the problem. Existing safety processes that may be adapted and extended to the worker fatigue problem include incident investigation and reporting and worker input procedures.

While safety tends to be viewed as a shared responsibility between management and staff in organizations, there are certain roles and responsibilities in construction firms that will likely have a closer connection with worker fatigue than others. These staff roles would most likely be superintendents, construction engineering planners, and labor crew supervisors. Planners have a key role in establishing specific construction tasks to be carried out, and this interacts with when they would be carried out—for example, the potential need for closures and night work. Superintendents tend to be aware of the pace and intensity of work and the likely productivity and safety impacts on workers. Crew supervisors would have a similar and more immediate understanding of fatigue issues on specific crew members.

BUILD IN FATIGUE MANAGEMENT

Assessment of the basic corporate approach to safety should lead to a concrete implementation step of building fatigue management into the overall process. The initial requirement for this step is management concurrence. As in virtually all corporate initiatives, leadership commitment is essential, not only for approving whatever resources may be necessary (and this may be a relatively small amount of personnel time in most cases), but also for reinforcing messages and business practices. Changes in scheduling need to be considered in terms of impact on overall performance, so fatigue mitigation is an appropriate issue for executive consideration.

Specific methods for incorporating fatigue management in the corporate safety approach include obtaining and analyzing data and enhancing safety training. In terms of data, information that reflects on the extent to which fatigue may be a problem is important. This may be as simple as repeated verbal reports from personnel concerning scheduling issues, or more detailed data reflecting productivity or safety incidents on different shifts. There will be wide variation across organizations in the nature of the data, and how data are obtained and analyzed, depending on the size and complexity of the contracting firm.

Safety training is one of the first lines of defense in fatigue management. While there are different models for training, such as new employee orientation and safety training, project-specific training, and daily crew briefings, each of these provides an opportunity to incorporate information about fatigue management. The team also has created two slide presentations, one for general highway workers and one targeted at managers, which can be used to train workers about the dangers and mitigation of fatigue in highway construction projects. These presentations are available at www.trb.org/Main/Blurbs/168766.aspx.

DISPEL ERRONEOUS BELIEFS

There are a number of inaccurate attitudes and beliefs held by a considerable percentage of workers, and a lower percentage of management, concerning fatigue and how to deal with it. These beliefs tend to transform into "myths" over time, influencing how people think and communicate about fatigue, regardless of accuracy. Some of these inaccurate beliefs include

- Fatigue is something to muscle through;
- Fatigue management is a personal responsibility;
- Fatigue is inevitable;
- Napping is not okay in the workplace; and
- Everyone has enough time off for recovery.

To the extent that beliefs such as these prevail and are perpetuated as myths through various elements of the workforce, fatigue will not be treated seriously. Thus, an important continuing process is to gradually dispel these beliefs and alter the cultural view of fatigue.

Science-based training can form the basis for addressing erroneous beliefs, through use of such material as provided in Chapter 3 and the online material. Training can help to shift the conception of fatigue from that of "inevitable annoyance" to that of "safety problem" and establish a basis for cultural change to seriously address it through fatigue risk management.

ANALYZE FATIGUE RISK TRAJECTORY

To facilitate the process of dispelling erroneous beliefs about the problem of fatigue, use an analytic framework that clearly shows fatigue is a cause of safety issues. The fatigue risk trajectory (Figure 2.2) provides a means for understanding the pathways to safety problems that can be used by safety managers for initial job, task, and schedule analysis. The basic trajectory involves sleep obtained, on-the-job fatigue, fatigue-related errors, and opportunities for sleep provided by work schedules. Behavioral outcomes and countermeasures associated with these risk factors can be used as a basis for intervention.

An illustration of how the fatigue risk trajectory can be used to analyze potential error-prone situations is shown in Figure 2.3. Errors occur when "holes" in the defensive layers align and prevailing circumstances enhance their likelihood. An example would be a maintenance-of-traffic worker scheduled on successive 12-h night shifts and getting less than 5 h of sleep during each off period. That individual is fatigued cumulatively throughout the week and may fail to implement traffic routing procedures

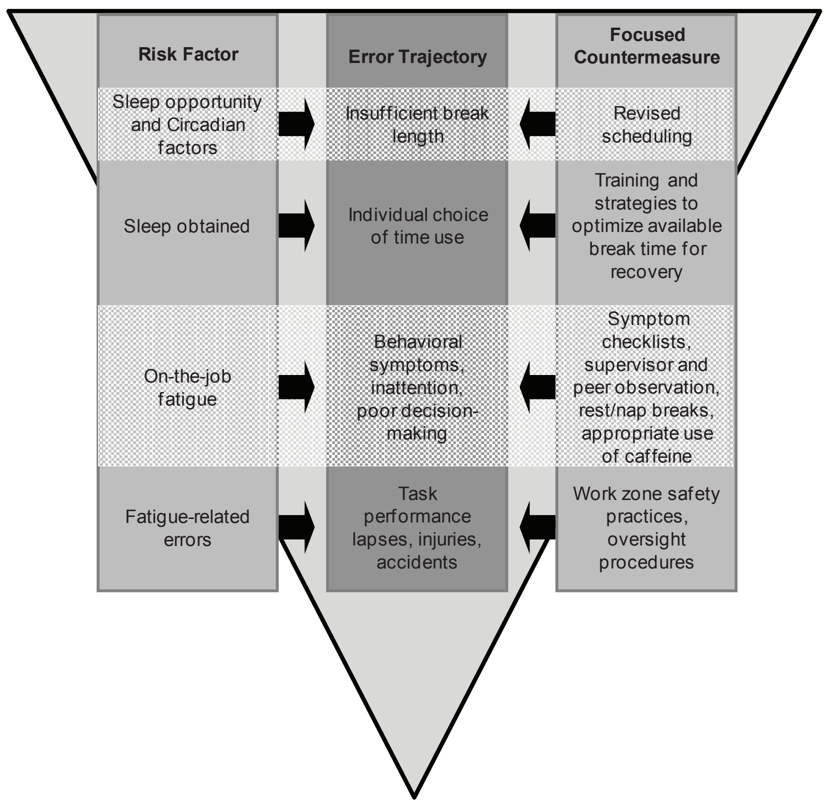

Figure 2.2. *Fatigue risk trajectory.*
Source: Adapted from Dawson and McCulloch 2005.

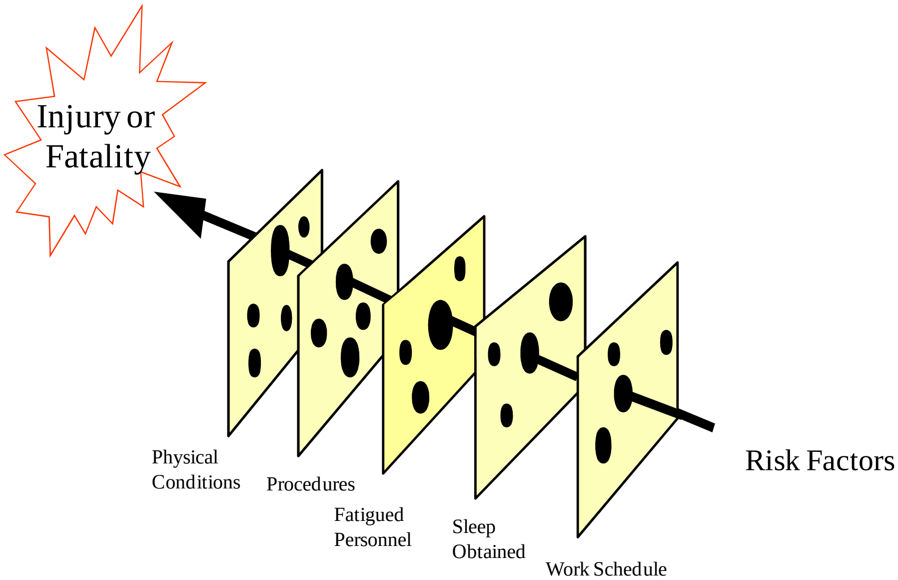

Figure 2.3. *Fatigue risk trajectory and multiple levels of defense.*
Source: Adapted from Reason 1990.

correctly. Due to schedule pressures or lack of personnel to verify the placement of traffic routing diversions or conditions such as poor visibility or rain, errors are not noticed and the result is vehicle incursion into the work zone with resulting injuries. Similar problems could occur with setting up construction equipment or rigging, putting multiple personnel at risk. Critical in this perspective on error causation is that multiple problems line up to cause an incident or accident, and fatigue is often one of those problems and therefore a risk factor to be managed and mitigated (Van Dongen and Hursh 2010).

ASSESS SCHEDULE RISKS

A systematic approach to risk assessment can use knowledge of how fatigue occurs over the course of work periods for staff on various schedules. This can be facilitated with a computer-based model, although for most construction firms some heuristics based on model outputs contained in the work schedule guidance provided in Chapter 4 will likely be sufficient. Models can be used to determine likely fatigue levels for workers, based on the schedules they are assigned to and how long they have been on those schedules. This information can be used to evaluate the recovery opportunities provided by existing and planned worker scheduling. Construction planning for specific skills and crafts across the 24-h period in different phases of projects will influence worker scheduling. Planners should evaluate the impact of construction scheduling requirements in terms of worker fatigue impacts and try to ensure that work schedules dictated by construction requirements do not adversely affect individuals or groups of workers. The models can also show when commuting is likely to be a safety issue, such as the night shift, when driving home occurs at the peak fatigue level.

Fatigue profiles such as this are also useful for evaluating napping opportunities—when they might occur in the work shift and what the impact on fatigue levels would be. For example, if there is a desire to reduce peak fatigue prior to driving home after a night shift, fatigue profiles can be used to show the increase of fatigue throughout the night and provide comparative profiles with and without naps. Similarly, use of earlier work stop times on shorter night shifts can be compared with later start times to show daily peak levels and also accumulation throughout the week.

Finally, it is important to address the work hours of designers and managers, especially as they work night shifts following day shifts or participate in long closures followed by a full week of day-shift work.

FORMALIZE RISK ASSESSMENT PROCESS

Implementation of the risk assessment process should become a regular activity, starting with analysis of contract opportunities, and continuing through the bid, construction planning, and execution of each project phase. Since rapid renewal projects often involve alteration of construction activities due to emergent circumstances, any schedule revisions should be reviewed as well. For example, scheduling of crew involves interaction between construction engineering and crew superintendents, and to the extent that superintendents see certain work crew affected by, say, too much night work, they should negotiate the execution of various construction tasks so that crews are provided with recovery opportunities. This may involve work breaks, naps at the worksite during night shifts, rescheduling certain tasks for day work if possible, increasing staffing, and generally providing relief from constant night work.

Fatigue risk assessment also can be used as a formal process for construction planning as well as for determining schedule and fatigue impacts of projects in the bid evaluation stage. For example, if a request for proposal contains incentives for completion or a specific number of closures permitted, modeling could be used to determine the work schedules required, availability of crew for such schedules, and potentially whether the project warrants bidding. If schedule modeling were to show night work at a level that management considers unsustainable, alternative approaches might be proposed.

IMPLEMENT COUNTERMEASURES

Countermeasures for fatigue are an important component of an overall organizational approach. The primary countermeasure is education and awareness for all personnel, including management, to dispel the myths and erroneous beliefs about fatigue and instill an understanding of the biological basis of fatigue and the things that can be done about it.

A few key countermeasures have been found to be effective in a variety of industrial environments, including defensive napping prior to night work and napping at appropriate times during the work period (such as the lunch break), caffeine during periods of high fatigue or to reduce sleep inertia (the fatigued feeling upon waking) after mid-shift naps, rest breaks from the work flow, and using scheduling to try to accommodate individuals who have varying susceptibility to fatigue.

One potential approach to a work break is to consume a caffeinated beverage just before a 30-min nap, and at the end of the nap the caffeine will be starting to take effect. If the caffeinated beverage is cold rather than hot, this may facilitate rapid consumption if time for the nap is limited. This approach will have the dual impact of reducing sleep inertia and reducing fatigue for the following several-hour period.

Countermeasures should be implemented as a relatively continuous process rather than a discrete implementation step. This is because conditions in rapid renewal projects are dynamic, and the specific approaches to implementation may vary with the schedule and season. For example, night work might be scheduled for a somewhat earlier start in the summer months, leading to a work stop time that allows workers to get home and into bed before it is completely light outside. It has been reported that this facilitates getting to sleep faster and sleeping somewhat longer, and circadian physiology supports this notion.

Fatigue countermeasures involve not only mitigating fatigue through rest breaks, offering better sleep opportunities, and so forth, but also addressing the fact that fatiguing schedules cannot be entirely eliminated. Night work is a fact of life in rapid renewal highway construction. In addition to addressing fatigue-reducing countermeasures, there are fatigue-proofing strategies for adding layers of defense against error. These include

- Increased supervisory oversight;
- Use of written procedures and checklists;
- Self- and peer-monitoring during critical periods;
- Reducing monotonous or highly complex tasks during periods of high fatigue;
- Extra personnel for critical and dangerous tasks;
- Nap timing for best impact;
- Interaction with peers to evaluate fatigue levels;
- Self-selected rest breaks;
- Transportation assistance following extended shifts; and
- Training for workers and managers in how to recognize fatigue.

By continually evaluating schedules and conditions of work, safety managers can adapt both fatigue-mitigating and fatigue-proofing countermeasures to prevailing conditions.

REPORT, INVESTIGATE, EVALUATE

The role of fatigue in construction safety problems is probably underrepresented due to lack of reporting and investigation. A proactive management approach to fatigue should encourage workers to report problems, whether they are related to scheduling, specific tasks, or even other workers.

In order to better understand specific project fatigue problems, safety incidents should be investigated with the fatigue factor in mind, including whether individuals worked many successive night shifts without a break, a weekend closure was involved, or individual workers were experiencing sleep restriction or sleep problems.

Commuting accidents, although technically not occurring during duty hours, can sometimes be related to fatigue from night work and are especially likely during rush traffic in the morning.

Information collected can be useful in modifying work schedules. A primary issue in implementing this step relates to the availability of data, determining what the current procedures are, if any, to document and investigate incidents and accidents. This will vary considerably across organizations based on their size and complexity. Trade and government organizations may play a role in providing standards and tools for structured data collection efforts.

The role of sleep disorders in contributing to workplace fatigue should not be ignored. Sleep disorders are associated with excessive daytime sleepiness and increased prevalence of motor vehicle accidents and occupational injuries. The majority of shift workers have a sleep disorder, and some sleep disorders can be caused by shift work. Common sleep disorders include insomnia, restless leg syndrome, and obstructive sleep apnea. Obstructive sleep apnea is particularly prevalent among men between the ages of 30 and 60, a risk that increases if they are overweight. Evaluation and treatment of sleep disorders has benefited the trucking industry.

SUMMARY OF ORGANIZATIONAL PRACTICES

Integration of the organizational practices described in this section is captured by Figure 2.4. An overarching safety management system can be anything from informal processes conducted by an individual part-time safety officer in a small firm to a more formalized structure with procedural mechanisms and formal reporting documentation and channels in larger organizations. The fundamental outputs of the organizational practices are the same: a deliberate and rational method for addressing and mitigating the impacts of fatigue on operational personnel.

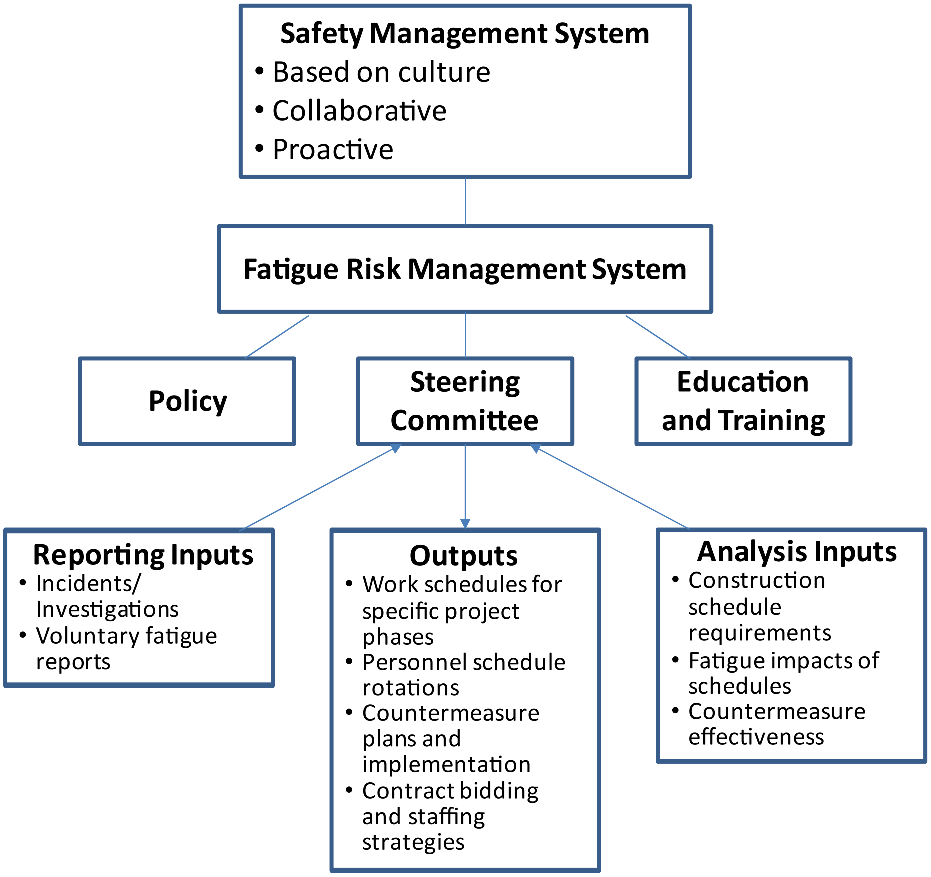

Figure 2.4. *Integrated elements of a Fatigue Risk Management System (FRMS). Source: Adapted from Gander et al. 2011.*

3 TECHNICAL REFERENCE MATERIAL

SLEEP BASICS

How to Use This Section

The information here (taken from McCallum et al. 2003) is organized as a set of individual topics that can be read sequentially or separately, depending on reader need. Individuals will get the best understanding of how alertness and fatigue result from sleep and brain physiology by reading the sections sequentially and then using the individual sections as reference material if they have questions later.

One may also copy or adapt the contents in each of these topics to develop educational materials to increase an understanding of the basics of sleep and alertness management for an organization.

Introduction

Everyone knows how it feels to get too little sleep. Many people refer to this feeling as “fatigue” or “sleepiness.” They are less alert, sometimes exhausted, tend to crave sleep, and may even nod off. The information in this section talks about the basis for alertness, that is, getting adequate sleep. The section also addresses the opposite situation: not getting adequate sleep, some of the reasons why this happens, and how it affects a person’s level of fatigue and alertness.

Sleep is based on brain physiology, and humans have specific requirements for getting adequate sleep. It is easier to sleep at certain times of our 24-h day than others because of brain mechanisms that have evolved over millions of years. The basic information in this section will help explain why it is necessary to get adequate sleep, why people sometimes do not, when workers might start feeling fatigued and how it affects them on the job, and what individuals can do to make sure they get adequate sleep.

Overview of Sleep Basics Topics

The following topics are discussed in the remainder of this section:

- circadian rhythms;
- sleep cycles;
- fatigue, alertness, and sleep loss;
- causes of sleep loss; and
- getting adequate sleep—how to do it.

Circadian Rhythms

The term "circadian rhythm" refers to the daily fluctuations in physiological and psychological functions controlled by the brain's biological clock. "Circadian" is a term from the Latin roots *circa,* meaning "about," and *dies,* meaning "day." The normal human sleep-wake cycle is based largely on the circadian rhythm, as well as alertness throughout the day. The brain mechanism that controls the circadian rhythm is located in the suprachiasmatic nucleus of the hypothalamus (Figure 3.1).

The brain's biological clock serves as a pacemaker for numerous daily cycles, including sleeping and waking, hormone secretion, digestion, body temperature regulation, performance capabilities, and mood. The biological clock programs humans to operate on a 24-h clock so that they are sleepy at night and awake during the day. Also, during daily waking, the circadian rhythm leads to predictable changes in alertness, such as the tendency to feel sleepy at some point during the afternoon (this is sometimes referred to as the "post-lunch dip," although the alertness drop has little to do with having eaten). Figure 3.2 illustrates the circadian rhythm in several physiological and psychological functions. It is noteworthy that when alertness is lowest (i.e., between midnight and 5:00 a.m.), melatonin levels are the highest; this is because secretion of melatonin by the brain leads to sleep onset. An individual's circadian rhythm is sensitive to external time cues, such as the level of sunlight and patterns of activity in the environment.

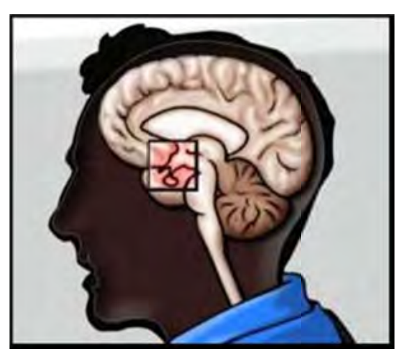

Figure 3.1. *Location of the brain's biological clock that controls circadian rhythms (indicated by square box).*
Source: McCallum et al. 2003.

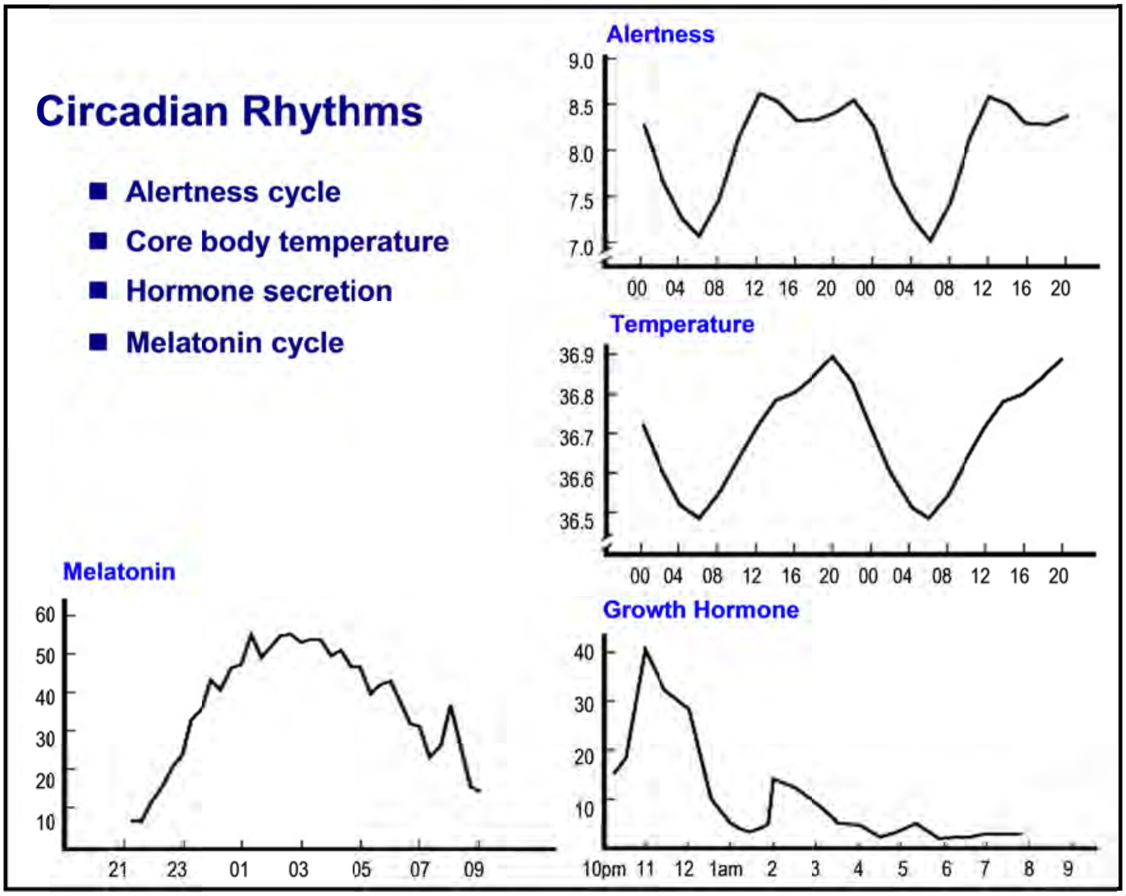

Figure 3.2. *Circadian rhythms for different physiological and psychological functions. Source: Adapted from multiple sources in Kryger et al. (eds.) 2000.*

Circadian rhythms are important to alertness management because they represent what the body was designed to do: sleep at night and be awake during the day. Work schedules that require people to be awake at night and asleep during the day are challenging primarily because of the circadian rhythm. The biological clock can adjust to different schedules or time changes, but this takes a certain amount of time, depending on how extreme the change is. Jet lag, for example, is a situation where the individual's rhythm is different from that of the local environment. After a few days in the new time zone people adapt. It is much more difficult, however, for people to adapt to work schedules that are opposed to their circadian rhythm, because the normal pattern of light and dark and daily activities are the same; they do not change as they do with a time-zone shift. Shift workers often switch from one activity-rest pattern to another, as on weekends, and their circadian rhythm becomes chronically misaligned with local time.

Circadian Rhythms: Key Points

- The daily cycle of sleeping and waking is controlled by a biological clock in the brain.
- Circadian rhythms affect alertness during the day.
- The biological clock is sensitive to external time cues such as light and social activity.
- Humans are programmed to sleep at night and be active during the day.
- Shift work opposes the circadian rhythm, leading to problems of sleep loss and low alertness.
- The circadian rhythm can be changed, but it is difficult in the presence of strong time cues.

When the circadian rhythm is not completely adapted to people's work-rest schedules, their on-the-job alertness is affected. This is because they are working when the brain is programmed to sleep, and they may not be getting adequate sleep during their off-work periods because of brain programming for wakefulness. This creates a chronic problem of sleep loss and low sleep quality, which further affects job performance and alertness.

Sleep Cycles

Sleep is a basic physiological need. Most people need about 8 h of sleep per night, although some may need as little as 6 h, while others may need 10 h. On an individual basis, the amount of sleep a person requires is that amount necessary to achieve full alertness and effortless functioning during the waking hours, even when sitting quietly and being bored. When people feel that they have to keep moving in order to stay alert, that is a strong sign of too little sleep.

Sleep is a physiological process that can be monitored by brain electrical activity. As people relax from their waking state, brain electrical activity slows progressively until the deepest level of sleep (Stage 4) occurs. Figure 3.3 illustrates the various stages of sleep, which progress through a cycle that repeats throughout the night.

A person drifting off to sleep enters Stage 1. This is followed by a slowing of the heart rate and relaxing of muscle tension as Stage 2 is entered. In Stages 3 and 4, slow wave brain activity is associated with very deep and restorative levels of sleep. During these stages it is particularly difficult to wake the person. Rapid Eye Movement (REM) sleep occurs throughout the cycle and shows a brain activity pattern similar to Stage 1 or waking; this sleep stage is associated with dreaming.

When people take a nap during the workday for about an hour or more, they are likely to fall into the deeper stages of sleep (Stages 3 and 4), and when they awaken from such deeper sleep, they are likely to experience "sleep inertia," which is grogginess that can last up to 15 or 20 min. To gain the benefits of a nap during the workday, and to avoid such sleep inertia, it is suggested that workers take a nap for about 45 min or less, as this decreases the risk of falling into the deeper sleep stages and having the inertia upon awakening.

With respect to a person's principal sleep for a 24-h period, it is important that the entire cyclic process of sleep be completed in order to receive the restful effects of a sleep period. Anything that interferes with sleep, such as noise disruptions, medication, alcohol, or simply insufficient duration, will change the physiological structure of the sleep cycles and impair alertness the next day.

Sleep is affected by aging. Although older people need as much sleep as younger people, they sleep less soundly and experience more awakenings during the night and shifts from one sleep stage to another. Medical conditions common in older people

Classification of Sleep

- **Awake**
- **Sleep**
  - **REM**
  - **Light**
  - **Deep**

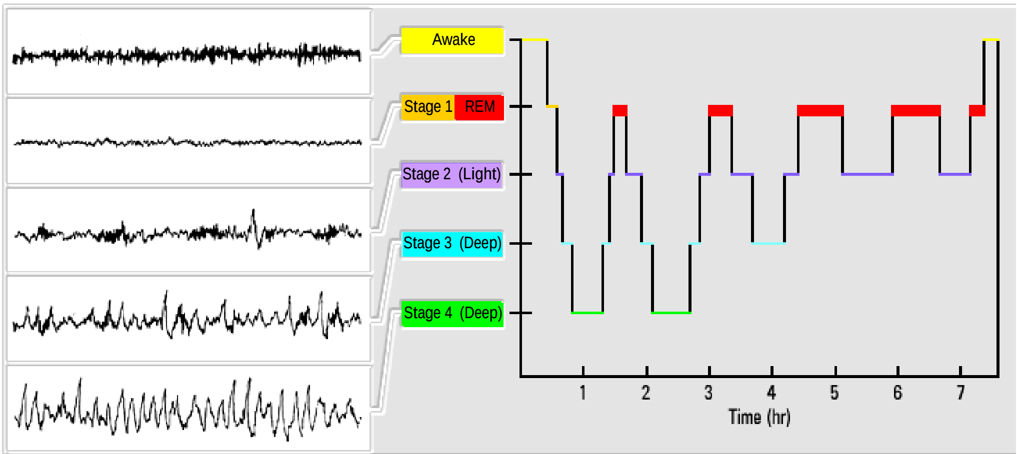

Figure 3.3. *Brain electrical activity (on left) illustrates the stages of sleep (on right), which progress in a cyclic fashion through the sleep period.*
Source: Adapted from Carskadon and Rechtschaffen 2000.

make sleep disruptions more likely. A prime result of sleep disruptions is increased daytime sleepiness and more napping during the day—which, paradoxically, can affect the quantity and quality of nighttime sleep.

People also differ from one another in their preferred activity and sleep times. "Larks" tend to be "morning people," arising early and getting to sleep early. "Owls" tend to stay up later at night and arise later in the morning. Owls tend to perform better on afternoon and evening shifts. People usually fall somewhere on a scale between a total lark and a total owl.

Fatigue, Alertness, and Sleep Loss

When people do not get adequate sleep, they experience fatigue and loss of alertness during the time they are awake. This affects their ability to perform safely on the job. Sleep loss of even 1 or 2 h can significantly degrade alertness and performance, with greater effects for increasing amounts of sleep loss.

If a person loses sleep over successive days, this can lead to an accumulated *sleep debt*. For example, if someone who needs 8 h of sleep only gets 5 h a night over 4 nights (i.e., over four 24-h days), the person would accumulate a sleep debt of 12 h. This can result in a cumulative effect on alertness and performance over that period of time. Frequently, we tend to gain some recovery sleep over our "weekends" or our 2 days off from work. Recuperation from sleep debt, however, requires getting more sleep for at least several nights. The effects of large sleep debts, say, not sleeping for 2 days, can still be detected in performance levels after a week of sleeping normally for 7 to 8 h per night.

Chronic sleep loss can contribute to health consequences, including obesity, diabetes, and high blood pressure. Even young people who experience sleep debt over a week show increased likelihood of infection and stress effects. Shift workers commonly experience sleep loss and are more prone to gastrointestinal disorders, as well as aggravations of cardiovascular disease and diabetes.

If there is enough reduction in sleep, people will reach a level of critically reduced alertness in which sleep spontaneously intrudes into wakefulness. These uncontrolled sleep episodes (microsleeps) can occur even when a person is standing up or operating equipment. It is important to recognize the signs and symptoms of fatigue and to ensure that workers are getting sufficient rest to maintain alertness on the job.

Sleep Cycles: Key Points

- Sleep is a basic physiological need.
- Sleep is a complex process consisting of multiple stages, some "deeper" and more restful than others.
- REM sleep occurs throughout the night and often involves dreaming.
- Upon awakening, people experience temporary grogginess called "sleep inertia," which usually disappears in 15 min.
- Anything that interferes with the duration or cyclic structure of sleep will reduce alertness the next day.
- Aging is associated with increased sleep disruptions, leading to daytime sleepiness.
- People differ in their preference for early or late schedules (larks versus owls).

Causes of Sleep Loss

One of the main causes of sleep loss is shift work if it occurs outside the normal daylight routine. Figure 3.4, a and b, shows the typical pattern of day work and night rest. This pattern is altered, or sometimes reversed, for shift workers and can lead to difficulties sleeping. The primary reason for sleep loss in shift workers is that they are trying to sleep at times when the brain's biological clock mechanism signals that they should be awake. As a consequence, shift workers may find it more difficult to go to sleep or to sleep as long as they wish.

Social and family demands can contribute to the sleep loss problems experienced by shift workers, because they may choose to spend more time in these activities at the expense of trying to rest. Many people who work afternoon or night shifts revert to a normal daytime schedule on the weekends or days off, in order to synchronize with the world at large. This can lead to a constant state of "circadian desynchronization," in which the body and the daily clock are in conflict.

A number of substances can interfere with sleep, including caffeine, alcohol, and over-the-counter drugs such as decongestants. The effects of caffeine typically last for about 4 to 5 h, but may last up to 10 h in especially sensitive individuals, so a cup of coffee after dinner may well interfere with getting to sleep. Similarly, alcohol may initially relax a person and assist in getting to sleep, but as it is metabolized there will be a "rebound" alerting effect, causing a person to awaken more easily. Alcohol also interferes

Signs and Symptoms of Fatigue

- Forgetful
- Poor decision making
- Slowed reaction time
- Reduced attention
- Poor communication
- Fixated
- Apathetic
- Lethargic
- Bad mood
- Nodding off
- Itchy eyes
- Need to sit

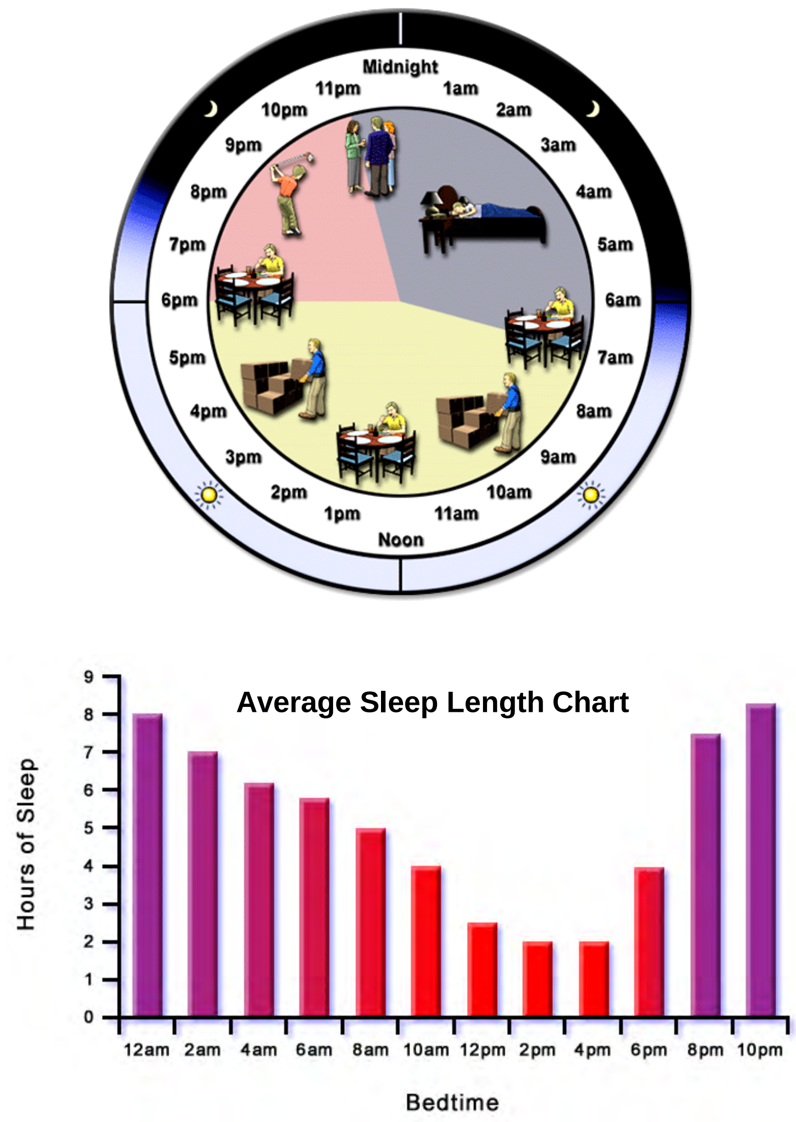

Figure 3.4. *(a) The normal daily routine for sleep and work and (b) sleeping at times not favored by the brain's biological clock results in less sleep.*
Source: Adapted from Åkerstedt 1995.

with REM sleep. Nasal decongestants interfere with sleep because they contain pseudoephedrine, which is a stimulant.

Other activities that may interfere with sleep include eating and exercise. Food consumption stimulates gastrointestinal reactions that may result in discomfort and sleep problems. Exercise on a regular basis is good for promoting sound sleep but should not be done within an hour or two of bedtime because it has an alerting function and can shift the biological clock forward.

Causes of Sleep Loss: Key Points

- Shift work causes conflicts between the brain's biological clock and when a person works and sleeps.
- Daytime sleep periods result in less sleep because of the influence of the biological clock and family and social demands.
- Caffeine, alcohol, and over-the-counter decongestants interfere with sleep.
- Food or exercise too close to a sleep period can result in sleep loss.
- Specific sleep disorders such as insomnia or sleep apnea cause sleep loss.

Specific sleep disorders also result in sleep loss. Among the most common of these are medical conditions such as congestive heart failure and arthritis that lead to the symptom of insomnia, which is difficulty in getting to sleep or staying asleep. Another condition, sleep apnea, affects as many as five out of every 100 people and is a breathing disorder involving periodic interruptions of breathing during sleep. Key signs that a person has sleep apnea are reports from others that the person snores loudly and irregularly when sleeping. Medical specialists can be consulted to determine if a specific condition exists that is interfering with sleep, and proper medical interventions can help to alleviate the problem.

Getting Adequate Sleep—How to Do It

The demanding world we live in makes getting adequate sleep challenging. But knowledge of some basic information and approaches can help people make the most of their rest periods to obtain sufficient sleep so they will be alert on the job.

There are four basic areas to consider for ensuring that a person gets adequate sleep:

1. The personal sleep cycle;
2. Sleep environment;
3. Relaxation; and
4. Things to avoid.

Understanding the individual sleep cycle is crucial for taking the steps to ensure sufficient restorative sleep. People can determine their optimum sleep amount by recording their sleep start and stop times on their third consecutive day off when they are not using an alarm clock to wake up. This is most likely to occur when taking a vacation.

The amount of sleep needed should be enough to feel refreshed and healthy the next day but not more; this will usually be between 7.5 and 8.5 h. Based on the amount of sleep needed, people should establish a habitual time for going to sleep and waking up and maintain this schedule whether or not it is a workday. Additionally, daily exercise helps to promote sounder sleep.

The sleep environment should be quiet and dark, using room-darkening shades if necessary. Earplugs can be helpful if there is noise. The temperature of the sleeping room should be around 65°F, and the bed should be used only for sleeping, not for activities such as reading or television watching.

Relaxation can promote falling asleep. The most basic technique is to wait until feeling sleepy to go to bed. People who are not tired should do something quiet and relaxing like reading or watching television in dim light until they feel sleepy. Once in bed, if they cannot sleep, they should get out of bed and do some quiet activity until they feel sleepy.

Getting good sleep depends on knowing what to avoid prior to sleeping. Especially important is to avoid caffeine within about 5 or 6 h of going to sleep, since the effects can last that long. It is also important to avoid drinking alcohol within 3 h of bedtime, since alcohol fragments sleep and makes it less restorative. Cutting down on or eliminating nicotine is important for promoting good sleep. People should also try to avoid thinking about the day's problems, possibly by writing "to do" lists for the next day to get things off their minds. Drinking fewer fluids before going to sleep will reduce awakenings to use the bathroom. Finally, a nap during the day helps only those who have no trouble going to sleep at night.

**Getting Enough Sleep—
How to Do It: Key Points**

- Make bedtime and waking a routine schedule to get the amount of sleep needed.
- Ensure the environment is dark and quiet and not too warm.
- Relax prior to bedtime; do not toss and turn. Get out of bed and do something quiet until becoming sleepy.
- Avoid caffeine and alcohol prior to bedtime, eliminate nicotine, drink fewer fluids to reduce use of the bathroom, and avoid thinking about problems.
- Nap during the day only if it does not interfere with going to sleep.

FATIGUE COUNTERMEASURES

This section identifies and discusses promising techniques for fatigue management and mitigation in highway renewal projects. Table 3.1 provides a summary. While there are clear beneficial effects of many of the countermeasures to be discussed, there is no "magic bullet" for fatigue prevention and mitigation. It is important to take an eclectic approach and to use measures that have been shown to work and that are adaptable to the circumstances at hand. The detailed technical basis for the countermeasures described in this guide can be found in the R03 technical report, *Identifying and Reducing Workforce Fatigue in Rapid Renewal Projects*.

1. Adequate Sleep

Fatigue can best be prevented by ensuring adequate sleep opportunities, proper sleep-period timing, and appropriate accommodations.

Type of Countermeasure: Preventive

The most effective countermeasure for fatigue is to do as much as possible to prevent it from occurring in the first place. As the literature suggests, the primary culprit for feeling fatigued is sleep loss. So, whatever can be done to obtain regular sleep and to prevent sleep loss should be high on the list of countermeasures. The principal advantage of getting enough sleep is that it will reduce on-the-job fatigue, thereby reducing the need for other countermeasures.

TABLE 3.1. FATIGUE COUNTERMEASURES CLASSIFIED BY TYPE AND JUDGED LEVEL OF EFFECTIVENESS AND IMPLEMENTATION COMPLEXITY

<table>
<tr><th rowspan="2">Impact</th><th colspan="2">Countermeasure Type</th></tr>
<tr><th>Preventive</th><th>Operational</th></tr>
<tr><td rowspan="2">Generally Effective</td><td>• Adequate Sleep
• Defensive Napping
• Good Sleep Environment
• Limiting Overtime and/or Work Schedule Modification</td><td>• Caffeine
• Napping
• Anchor Sleep
• Rest Breaks</td></tr>
<tr><td colspan="2">• Fatigue Education</td></tr>
<tr><td rowspan="2">Less Effective</td><td>• Diet</td><td>• Temperature and Ventilation
• Self- and Peer-Monitoring</td></tr>
<tr><td colspan="2">• Exercise</td></tr>
<tr><td>Limited Evidence or Implementation Complexities</td><td>• Hypnotics or Stimulants
• Model-Based Schedule Optimization
• Fatigue Risk Management System</td><td>• Worker Status Monitoring and Alerting Technologies
• Bright Light or Melatonin for Circadian Shifting</td></tr>
</table>

People need, on average, 7.5 to 8 h of sleep to not feel fatigued. The first general strategy for minimizing sleep loss is to establish a routine approach to obtaining sleep, one that allows enough time to get enough sleep, takes time of day (circadian rhythm) into account, and ensures an appropriate sleep environment. Ideally, this would mean going to bed at the same time every night and waking up at the same time every day, allowing for at least 8 h of time in bed. Recognizing that regular sleep times are often not congruent with everyday life, it is important to point out that day-to-day variations in sleep timing and duration can be overcome by sleeping in on days off and by supplementing sleep time with napping, provided that total sleep time is not curtailed in the long run. (This is not recommended in individuals diagnosed with insomnia, where sleep regularity is one of the pillars of sleep hygiene and typically considered essential for treatment.) The sleep environment should be quiet, dark, and of comfortable temperature.

Shift workers often change shift schedules from one week to the next, or more frequently. This can lead to sleep loss because the brain is not adapted to sleeping at a different time of day. The best approach for reducing sleep loss associated with a new shift schedule is to start the new shift with no sleep debt—as a rule of thumb, this means getting at least 2 nights of unrestricted sleep prior to beginning a new schedule. If making a radical schedule shift, such as between days and nights, it will also be important to obtain some compensatory sleep prior to the new shift start (see discussion of defensive napping). For example, if the schedule starts at midnight Sunday, it would be desirable to get 2 full nights of sleep on Friday and Saturday, sleep as long as possible on Sunday morning, and try to nap for a couple of hours before the start of the midnight shift on Sunday. Napping prior to extended periods of wakefulness will reduce fatigue and improve alertness.

A third general approach to minimizing sleep loss is to match sleep and work schedules to individual physiology. Morning people (i.e., "larks") perform best on work schedules with morning starts, but even for young people earlier than 7:00 a.m. is difficult. As an example, a study of construction workers on a typical three-shift system found that the day-shift workers got the least sleep, due to the 6:00 a.m. start time (Powell and Copping 2010). Night people (i.e., "owls") perform best on work schedules that start in the afternoon or evening. In either case, it is important that individual physiology be coupled with a sufficient main sleep period.

The limitations associated with this countermeasure tend to involve factors that often are beyond the control of the individual, such as work-shift start times, rotation of schedule, and location factors that might influence sleep, such as jet lag or the sleep environment. Additionally, some individuals tend to sacrifice adequate sleep for purposes of social or family activity; however, these factors involve individual choice and can be balanced as required.

Countermeasures to Minimize Sleep Loss

- Obtain sufficient sleep
- Have a regular routine for sleep
- Ensure the sleep environment is appropriate
- Start new shift schedules with minimal sleep debt
- Obtain compensatory sleep before a new schedule
- Match regular work schedule to personal physiology: "lark" or "owl"

Effectiveness

It is generally agreed in the fatigue research literature that adequate sleep is *the* most effective countermeasure to fatigue and performance decrements. The effects of adequate sleep last throughout the work period unless the work period is so long that it requires wake extension and thus causes sleep deprivation (although circadian rhythms will increase fatigue at night regardless).

Highway Construction Environment Implementation

Implementing the preventive countermeasure of adequate sleep involves a combination of worker knowledge and work schedule management to provide sufficient opportunity for sleep. As such, linkages to other countermeasures such as worker education and schedule management on the part of the construction contractor are important elements in getting adequate sleep.

2. Defensive Napping

This countermeasure involves sleeping for a brief period before the work shift.

Type of Countermeasure: Preventive

Taking a nap can help to reduce fatigue and increase alertness on the job, or at other times. Naps can be effective as a short-term countermeasure to fatigue, or to compensate for periods when a worker will need to remain awake for a long time, such as when changing shifts.

Some general situations where napping would be appropriate are

- Less than 6 h for the main sleep period.
- Awake for 30 min or longer two or more times during the main sleep period.
- Feeling as if continually drifting in and out of sleep.
- Feeling much more tired than usual upon awakening from the regular sleep period.

Taking a nap should be timed to obtain the maximum benefit. This will vary depending on circumstances, but in general the following guidelines are applicable:

- Napping for longer periods (2+ h) prior to the start of a night shift can prevent fatigue for extended periods (e.g., through a night shift) and can be very beneficial. Napping for short periods (less than 30 min) may result in subjective alertness, but little is known about how long this effect provides actual benefits.
- Individuals who are day oriented and not sleep deprived should avoid napping during the hours of 6:00 to 10:00 p.m., approximately, when alertness is usually high (the so-called "wake maintenance zone").
- Naps should be scheduled during the mid-afternoon (1:00 to 3:00 p.m.) when alertness is low.
- After a nap, individuals should allow 15 to 30 min to become fully alert. The deeper the sleep the longer the period needed to become fully alert.

Effectiveness

Napping as a defensive measure reduces fatigue in the work period approximately in proportion to the duration of the nap. Further, the timing of the nap in relation to the work period is important, such that a nap closer to the work period is generally more effective.

Highway Construction Environment Implementation

As with the preventive measure of adequate sleep, defensive napping is a matter of individual worker knowledge and the opportunity to act on that knowledge in advance of experiencing fatigue. The latter aspect is related to work schedule management, notification of shift change, and sufficient advance notice to allow workers to use the time available to them to adjust through napping. In practice, the construction companies the team interviewed attempt to give at least a day off prior to switching from day to night shift.

3. Good Sleeping Environment

A good sleeping environment sets the stage for restorative sleep.

Type of Countermeasure: Preventive

Although most people can get used to almost any sleep environment, especially when they are exhausted, certain characteristics of where an individual sleeps can enhance or compromise how restorative a rest period is.

To ensure that sleep is restorative, sleeping environments must be quiet, dark, and comfortable.

To ensure a quiet environment, the individual should remove any noise sources, especially those that are unpredictable (e.g., pets in the bedroom). Use of earplugs to reduce traffic noise or other external sounds helps many people, as well as the use of a constant low-level noise source such as a fan.

The amount of light in a sleeping area can be reduced by using blackout shades, heavy dark fabric for curtains, or "hurricane shutters" over windows. Some people also use eyeshades in areas where there is substantial light leakage.

Comfort in the sleeping environment is related to the quality of the bed and the temperature. The bed and pillows should be of appropriate firmness for personal comfort and the temperature not too warm or too cold by personal preference.

Two additional environmental recommendations include (1) orienting the clock face away so that the individual does not worry about the time, especially when having difficulty falling asleep, and (2) using the sleeping area only for sleeping, not other arousing activities such as work or watching TV and videos.

Effectiveness

The principal advantage to using this countermeasure is that an individual can adapt the sleep environment to meet individual needs and have a continuing positive effect on sleep quality.

Highway Construction Environment Implementation

The importance of sleep environment characteristics is primarily an educational issue. The fact that sleep hygiene principles are routinely suggested to individuals seeking sleep medicine consultation indicates the need for continuing education of workforces that may be subject to sleep disruptions. This can also include information to assist with modifying family routines to facilitate sleep for the affected individual.

4. Limiting Overtime and Work Schedule Modification

Type of Countermeasure: Preventive

Evidence suggests that longer-duration shifts and overtime are associated with increased incidence of error and safety-related incidents (Åkerstedt et al. 2002). The principal choices in limiting overtime or modifying the work schedule involve how long the shift will run, what time it will start, and which workers to assign.

Effectiveness

Limiting work hours and modifying work schedules are associated with increased worker satisfaction and reduced incidence of errors on the job by providing more time for sleep.

Highway Construction Environment Implementation

Implementation of this countermeasure in the rapid renewal highway construction environment involves a number of considerations. First, there appear to be only two basic shift ranges in the projects that the team evaluated: day work (approximately 7:00 a.m. to 5:00 p.m.) and night work (approximately 7:00 p.m. to 5:00 a.m.). These schedules seem to be a blend of traditional work hours during the day and hours set to accommodate late afternoon rush hour traffic in the evening and an early morning stop time. Thus, there are fairly rigid parameters associated with start and stop times that do not easily accommodate change.

Work scheduling during "regular" shifts, either day or night, appears to currently operate on the basis of project labor agreements (PLAs) for union states and common practice in non-union states. In either case, the usual approach to scheduling involves either 8- or 10-h shifts, with a maximum of a 55-h week. The usual minimum time off between consecutive work periods is 1.5 days.

The aspect of rapid renewal construction work that can most benefit from limitation of work hours or schedule modification is the practice of continuous weekend closures. These closures tend to run from 11:00 p.m. Friday evening to 5:00 a.m. Monday morning and are associated with considerable sleep disruption among managers, and possibly among laborers. Current practice on accelerated projects is to continue using the same workforce for another week of standard day or night work schedules following a weekend closure. Workers show high levels of fatigue following this type of closure and resumption of a standard schedule. A simple modification to this practice is to provide workers Monday off following a weekend closure, or at least to implement a later start time. The project gets less work accomplished on that Monday, but this may still be a beneficial trade-off because of the lower productivity expected of fatigued workers.

5. Fatigue Education

Type of Countermeasure: Preventive and Operational

An understanding of the fundamental nature of sleep loss, circadian rhythm, fatigue, performance impacts, and amelioration strategies is a key element of both preventive and operational approaches to reducing fatigue. Education is a basic element of current approaches to Fatigue Risk Management Systems (FRMS), and it can help to overcome widely held misconceptions about the nature of the problem and ways to deal with it.

Key points to address in educational programs include the following:

- In the long run, there is no substitute for sleep.
- Fatigue is based on physiological mechanisms and cannot be overcome by motivation or willpower.

- Self-assessment is unreliable and potentially biased by work circumstances.
- Individuals vary in sleep need and responses to sleep loss, and it is difficult to predict on a case-by-case basis.
- There is no “one-size-fits-all” solution.
- There are ways to prevent and mitigate fatigue, but they must be properly employed.
- Fatigue has safety, well-being, and economic consequences.

Effectiveness

Although training is sometimes considered a weak response to structural, organizational problems such as fatigue, it is a necessary first step in gaining commitment at the individual and corporate levels to address the problem. Simply having an educational program is no guarantee of results, and some studies suggest that knowledge decays rapidly. Other studies indicate that higher levels of corporate commitment and engagement lead to longer-lasting impressions.

Highway Construction Environment Implementation

While important as a fundamental component in fatigue management, translation of existing scientific knowledge into usable programs for employers and workers is not straightforward. Educational programs could be imported and adapted from transportation industries such as commercial aviation. Comprehensive and contextualized training about fatigue for the rapid renewal environment will need to address the specific risk factors and operational constraints of the work domain. These include long shifts, occasional double shifts, rapid switch to night work from day work, and continuous weekend closure effects upon sleep opportunity.

6. Napping

Type of Countermeasure: Operational

This countermeasure involves sleeping for brief periods during the work shift.

It is important to consider the following:

- Where to take the nap.
- When to take the nap.
- How long to nap.

In general the following guidelines specific to workplace napping are applicable:

- Taking 10- to 12-min “power naps” almost anytime as needed and appropriate can help refresh an individual for a short period of time.
- Awareness is needed of the potential effects of sleep inertia following the nap and the need to counteract the effects with caffeine if necessary.
- Napping should be used as part of a continuous, non-split shift duty period and not as a means to extend the duty period.

Effectiveness

Naps of 20 to 30 min during appropriate periods of a work shift have been shown to improve performance and subjective alertness during the subsequent work period. Studies of extended shifts (16 h) have included naps of up to 2 h, although this tactic has entailed more sleep inertia and potential interference with recovery sleep during the off-work period.

Highway Construction Environment Implementation

Implementing on-shift napping in a highway construction environment may be a considerable challenge. Field studies suggest that some workers do take naps during their lunch breaks or other times when it is appropriate, and they tend to use their personal vehicles as the location for napping. Due to the safety-critical nature of construction, workers must be very cautious about where and when they take breaks, particularly if they are asleep for a brief period. Personal vehicles as a location for napping are probably relatively safe, although ultimately it would be desirable to optimize the conditions under which naps are taken, in order to avoid excessive noise, vibration, overheated vehicles from sun exposure, and potential contact with construction equipment.

7. Caffeine

Alertness can be increased by consuming caffeine in the form of coffee, tea, soft drinks, chocolate, caffeine gum, or non-prescription caffeine tablets.

Type of Countermeasure: Operational

Caffeine is one of the most commonly used fatigue countermeasures, usually obtained through a cup of coffee. Other popular drinks and foods contain a lot of caffeine, including cola drinks, chocolate, and tea. Numerous medications also contain caffeine, as do "alertness aids" such as No-Doz and Vivarin. Caffeine is widely available, and taking a brief break to take caffeine can have the additional advantage of breaking up a tiring work routine.

Caffeine affects the nervous system within 15 to 20 min, depending on the mode of ingestion. The effects include a more rapid heartbeat and increased alertness, and they last for about 4 to 5 h but may last up to 10 h in especially sensitive individuals.

It is important to use caffeine only as a short-term way to boost alertness; regular use can lead to tolerance and various undesirable side effects, including insomnia and disrupted sleep if taken too close to bedtime.

Here are some situations in which using caffeine makes sense:

- In the middle of a night shift (especially on the 1st and 2nd day of the workweek when circadian disruption tends to be most pronounced and alertness most compromised).
- Mid-afternoon when the post-lunch alertness dip is greater because the individual did not get enough sleep.
- Prior to an early-morning commute following a night shift, but not within 4 h of going to sleep if the individual is sensitive to sleep disruption from caffeine.
- Prior to a brief nap of 15 or 20 min, to reduce the effects of sleep inertia from the nap. Caffeine effects will become active as the nap is ending.

It is always best to try to reduce fatigue through obtaining enough sleep, but when this does not happen and boosting alertness for a period of several hours is needed, using caffeine makes sense.

Caffeine will affect sleep and should not be consumed 4 to 5 h prior to sleep, unless the individual is not sensitive to caffeine disruption of sleep. Caffeine in the body will make falling asleep more difficult, reduce sleep length, and disrupt the quality of sleep.

Human brains gradually build up a tolerance to repeated consumption of high levels of caffeine (e.g., more than five cups of coffee per day). A frequent coffee drinker needs a higher dose of caffeine to obtain the same "boost" effect of the more casual coffee drinker. Caffeine should be consumed sparingly, to "save the boost effect" for when it is really needed. That is, plan to use caffeine in the middle of the afternoon dip (1:30 to 3:30 p.m.) or, if working through the night, use it after midnight during the circadian low point.

Effectiveness

The alertness-enhancing effects of caffeine have been well documented, and performance is increased on various measures when caffeine is used, particularly if people are sleep deprived. There are, however, considerable individual differences in the effectiveness of caffeine. The duration of the effects is sufficient to counteract moderate levels of fatigue, when taken in time periods when fatigue will be a problem. Further, some putative sources of "energy," such as high-sugar colas and energy drinks, are lower in caffeine per fluid volume than coffee and tend not to have the same alerting effects as drinks with higher amounts of caffeine.

Highway Construction Environment Implementation

This countermeasure appears to be well implemented on an individualized and informal basis in highway construction environments. Workers report either bringing their own caffeinated beverages to the job site or being able to obtain caffeinated beverages near the worksite. Contractors may also consider providing coffee or other caffeinated beverages at a central location to the worksite, for example, in the worksite office or at the location where "stretch and flex" safety meetings are held.

8. Anchor Sleep

Type of Countermeasure: Operational

Anchor sleep (or "split sleep") refers to a regular sleep period of at least 4 h obtained at the same time each day. The anchor sleep period is supplemented by an additional sleep period taken when the schedule allows.

Some work schedules do not allow a full 8 h of sleep at the same time period every day. In order to effectively cope with schedules like these, workers should arrange to get at least 4 h of sleep at the same time every day; additional sleep can be obtained as the schedule permits.

Anchor sleep periods have the advantage of stabilizing the circadian rhythm to a 24-h period, so that workers will not constantly feel "out of sync." The anchor sleep period should be timed so that circadian rhythm high and low points correspond to work and sleep periods.

Anchor sleep is not a substitute for getting a full 8 h during any 24-h period. Instead, it is a coping mechanism meant to keep an individual's circadian rhythm synchronized to the daily schedule, by allowing sleep for a period of time when sleep is possible. It is important to supplement anchor sleep with naps sufficient to provide the complete sleep allotment needed daily. This countermeasure is helpful because it anchors the sleep cycle.

Research data indicate that it is important to have the anchor sleep period occur at a constant time every day. It is important to try to time the main or supplemental sleep episodes so that they do not coincide with circadian "forbidden zones" (wake maintenance zones) when initiation of sleep would be difficult. Typically, these times are approximately 8:00 a.m. to noon (when not sleep deprived) and particularly 6:00 to 10:00 p.m.

Meals should be taken at the times that workers normally eat. When taking supplemental sleep, it is important that it not be too close to the anchor sleep period, or interference will occur. Caffeine consumption should be moderated during the use of anchor sleep as well, since the effects of caffeine last for about 5 h and may interfere with either the anchor sleep period or the supplemental sleep in individuals sensitive to this effect.

Anchor sleep should be used as a coping mechanism for situations when a worker cannot get a full 8 h of sleep, but not as a routine. While split sleep periods may provide a sufficient amount on a short-term basis, getting a sleep allotment in a single episode is preferred.

Effectiveness

Laboratory studies of anchor sleep and split sleep periods indicate that performance tends to be maintained at levels equivalent to getting a consolidated sleep period. It is not known if performance stability is maintained over weeks to months on such schedules.

Highway Construction Environment Implementation

Anchor or split sleep schedules would seem most appropriate for highway construction workers on continuous closure operations, particularly management personnel not covered by a specific labor agreement for daily work hours. An example would be a manager who wants to be at the start of a closure on Friday evening and work as much as possible through the following Monday morning. An anchor sleep strategy for this individual would be to nap in the mid- to late afternoon on Friday in preparation for staying up all night starting late Friday night. The manager could then return home to sleep early Saturday morning and probably get about 4 h of sleep prior to waking. The manager could return to the worksite for several hours, then take another long supplemental sleep in the mid- to late afternoon. This process would be repeated until the end of the closure on Monday morning.

9. Exercise

Type of Countermeasure: Preventive and Operational

Physical exercise has the principal benefit of improving overall cardiovascular health and muscle tone. Additionally, regular exercise improves sleep: individuals fall asleep more quickly and sleep more soundly depending on the timing and the type of exercise. Exercise also enhances feelings of alertness for a short period.

Physical exercise can also be used to reduce the feeling of fatigue resulting from not getting enough sleep. Research indicates that brief periods of exercise can reduce feelings of sleepiness, although job performance does not improve. In rested individuals, a morning exercise break may improve alertness and driving performance for a brief period afterwards.

The health benefits of regular physical exercise are clearly established, and individuals should consider initiating a regular program of exercise or maintaining what they are already doing. If they work irregular hours or in situations that limit what they can do (e.g., no ready access to a gym, or darkness), planning ahead and using alternative activities such as walking can be used to maintain a healthy activity level.

Regular exercise will contribute to feelings of increased energy by helping develop stamina and improving sleep. It should be a regular part of a healthy lifestyle.

While exercise will promote health and improve an individual's sleep, it does not permit one to cut back on primary sleep. Exercise can reduce immediate feelings of fatigue resulting from schedule changes and sleep deprivation, but that feeling only lasts for about 30 min. The effects of exercise on job performance are complex and tend to wear off quickly, possibly even making performance worse in the afternoon. So, while individuals may feel better after exercising during a sleepy period on the job, they are still fatigued and should be aware that performance is likely to be compromised.

Do not exercise too close to bedtime, because increases in body temperature and alertness may make it difficult to go to sleep.

Effectiveness

Exercise as a fatigue countermeasure should be used primarily to develop cardiovascular health and to promote healthy sleep. As such, exercise is a complementary countermeasure and can facilitate the primary goal of getting adequate sleep. Exercise can be used as a very short-term countermeasure for brief enhancement of alertness, but the effects may not transfer to actual performance and will not last throughout the work period.

Highway Construction Environment Implementation

Implementation of this countermeasure in the highway construction environment as a preventive countermeasure may be promoted through the regular use of morning safety meetings and "stretch and flex" exercises that are part of this routine. It is common practice with some contractors to hold these crew-mustering meetings prior to initiation of work, to discuss recent safety concerns and promote physical warm-up. These meetings could also be used as a platform for promoting regular exercise in the off-work hours to enhance health, restorative sleep, and general alertness. It should be borne in mind, however, that well-intentioned advice to get up early to exercise is counterproductive for fatigue management if arising early curtails the sleep period.

10. Diet

This countermeasure involves varying meal content in order to increase alertness or promote sleep.

Type of Countermeasure: Preventive

The physical activity associated with eating can itself induce an alerting effect; however, current research evidence suggests that specific food content has little, if any, impact on the level of alertness or feelings of sleepiness.

An attempt to extend an individual's endurance or promote sleep by altering the content of meals is unlikely to succeed. It is better to focus on consuming a nutritionally healthy and balanced diet at the appropriate times of day.

Getting a balanced, nutritious diet at appropriate times is often difficult for shift workers. Schedules often limit eating to what is available when time and work permit.

Individuals can avoid this situation with appropriate planning. Packing meals prior to leaving home, taking breaks where supermarkets are located, and obtaining take-out meals from (non-fast-food) restaurants are some steps that can be taken to make sure the right foods are available when needed.

Whenever possible, individuals should try to eat meals at times that correspond to their normal mealtimes. This will help maintain a regular sleep-wake cycle, since meals are a time cue that influences circadian rhythms. Conversely, the gastrointestinal system will process food best when it is eaten at the right times of day. One of the primary complaints of shift workers is gastrointestinal discomfort caused by being forced to eat at night when the body is not optimally prepared to handle the food intake.

Consuming large meals prior to sleep can disrupt the subsequent sleep period and also result in gastrointestinal discomfort.

Effectiveness

Eating properly is a key element of overall general health, which can contribute to quality and quantity of sleep. Eating or drinking specific foods or beverages (other than caffeine) for alertness enhancement is unlikely to work.

Highway Construction Environment Implementation

Good dietary habits and meal content could be part of an overall fatigue, health, and wellness training program for highway construction workers. There are no specific recommendations for dietary content for workers in this domain.

11. Rest Breaks

Rest breaks from the performance of a work task can reduce the effects of sleep loss for a short time.

Type of Countermeasure: Operational

Research studies have demonstrated that people who are sleep deprived or work on continuous but monotonous tasks during the night show degradations in their performance. However, if they take breaks, sometimes as short as 7 min, the degraded performance is reduced and they also feel subjectively better. The effects of the rest breaks last only for 15 to 25 min, but they can be very important during critical tasks that are safety sensitive.

The break does not have to involve napping but instead simply a change in activity, such as stopping whatever task the worker is currently engaged in, walking around, stretching, talking to others, and so forth. The breaks may have more impact on fatigue later in the work cycle.

An additional benefit of a rest break is that it temporarily removes the worker from the worksite, and thus from potential risks.

Effectiveness

Rest breaks can provide temporary relief (of 15 to 25 min) from performance declines and subjective fatigue due to sleep loss. They are a short-term measure and not a substitute for adequate sleep.

Highway Construction Environment Implementation

Most highway construction jobs are to some degree self-paced, which allows workers to take breaks when needed. There are certain multi-person, time-intensive tasks, such as pavement finishing, that would not be conducive to individual decisions to take a break, but with team support, rest periods could be agreed upon.

Rest periods for "work to completion" kinds of tasks should be considered by construction superintendents. They should be planned for on the basis of when fatigue is likely to be a problem, such as toward the middle or end of a night shift or closure period, or to break up a monotonous or physically demanding task.

12. Temperature and Ventilation

This countermeasure involves changing airflow and temperature in the surrounding environment to increase alertness.

Type of Countermeasure: Operational

Altering the airflow and temperature in the surrounding environment is fairly easy for most workers, through control of air conditioning or increasing fresh air by opening a window.

It is important to ensure that the air quality in the immediate operational environment is good, since fatigue is one of the symptoms often associated with impurities in the air. The fatigue that results from impurities can be a physiological reaction to reduced oxygen and is an indication that the environment should be changed. For highway construction workers, air impurities might result from improperly ventilated exhaust systems or fumes from construction material such as asphalt.

Temperature tends to affect alertness indirectly by changing the overall comfort level. If an individual is inclined to feel sleepy anyway, a warm environment may increase those feelings. However, the opposite is not true: There is little benefit to opening a window or lowering the temperature if an individual is already fatigued.

While there may be a brief effect of lowering the surrounding temperature or increasing airflow, research data suggest that the impact is very short and not likely to increase alertness for longer than a few moments. So, if an individual is feeling sleepy, it is best to use another countermeasure.

Effectiveness

Changing temperature, ventilation, or both may enhance alertness momentarily but it is not an enduring effect and should not be considered a practical countermeasure.

Highway Construction Environment Implementation

Given the only momentary effects of changing temperature or ventilation, use of this countermeasure in the construction environment should be limited to short-term supplementation of other countermeasures, such as rest breaks or exercise.

13. Self- and Peer-Monitoring

This refers to observing self or co-workers to assess levels of fatigue.

Type of Countermeasure: Operational

Performance impairment does not necessarily indicate fatigue, and self-report of fatigue does not necessarily indicate performance impairment, but the likelihood of one is increased in the presence of the other. For these reasons it is important that workers pay attention to their own subjective state as well as monitor the quality of their work.

There are various rules of thumb that workers can use to self-monitor. These include knowledge of their prior sleep-wake patterns, overt symptoms such as yawning, drooping eyelids, “catching” themselves falling into microsleeps, and feelings such as “fighting sleep”—items also featured in one of the most frequently used fatigue rating scales.

People are aware of their fatigue as it is developing and influencing their performance, including safety incidents, and this awareness strongly correlates with physiological measures of fatigue such as brain wave measurements. The self-awareness of fatigue state needs to be linked to knowledge of proper actions (such as taking a break), so that people will not try to fight fatigue with relatively ineffective countermeasures. However, it is also known that fatigue impairs judgment and self-regulation, and so self-observation and report should not be relied upon exclusively.

Fatigue involves subjective feelings of tiredness, behavioral patterns of omissions and taking shortcuts, and a physiological basis. Observation of worker behavior by peers or supervisors relies on the observer’s ability to distinguish specific behavioral characteristics indicating impairment. A variety of symptom checklists have been employed by researchers, primarily as adjuncts to primary methods such as physiological or self-report measures. The checklists include facial markers such as eye closure, loss of facial muscle tone, and so forth, as a basis for determining likely state of alertness. The behaviors may occur without indicating an underlying state of fatigue, or the state of fatigue may be momentary. Fatigue may also be present without the overt symptoms, or with the overt symptoms occurring only occasionally and, therefore, be difficult to observe. The successful use of observational approaches depends on the ability of the observer to distinguish "normal" behaviors from those clearly indicating impairment and to do so on a near-continuous basis, because fatigue is a dynamically changing state. This makes peer or supervisor observation an unreliable method for detecting fatigue. That said, workers should be encouraged to alert others when observing potentially fatigue-related behaviors, because fatigue is likely present when the symptoms are readily noticeable.

Effectiveness

Research indicates that individuals can reliably self-assess their own momentary state of fatigue and less reliably assess others. The overall effectiveness of this approach depends on knowledge and ability to act on the assessment of fatigue. This becomes a matter of implementation.

Highway Construction Environment Implementation

Interviews with construction superintendents suggest that they have certain rules of thumb for determining when their crews are fatigued, including erratic performance, facial characteristics, irritability, and knowledge of their prior schedule. Superintendents also state that they are aware of which individuals are more likely to be able to work certain hours and schedules, and they are aware of each worker's propensity to fatigue. They construct schedules and assignments to the extent they are able on the basis of that knowledge.

These findings suggest that supervisory monitoring is already taking place, albeit on an informal basis. There may be a role for approaches to "fatigue-proofing" highway construction environments through a combination of training on fatigue effects and how to recognize them and more clearly establishing criteria for recognizing fatigue on the job and what to do about it. Examples from other work environments include using more humor and joking around on the night shift to see how people respond; those showing unusually low response or irritability (compared to their usual personalities) would be watched or backed up more closely in safety-critical tasks.

14. Hypnotics or Stimulants

Type of Countermeasure: Preventive

This countermeasure involves the use of synthetic or natural drugs to promote sleep when schedule changes interfere with falling asleep, or the use of synthetic or natural drugs to reduce the effects of sleep loss and enhance alertness under conditions of fatigue.

Hypnotics

If a worker has a sudden change of schedule that interferes with the ability to go to sleep, there are drugs and herbal substances that can be used to promote sleep. Hypnotic drugs such as Ambien are part of a class of drugs that are useful for inducing sleep. These drugs reduce the amount of time required to fall asleep, improve ability to stay asleep, and can maintain sleep for 7 to 8 h.

Herbal remedies such as Valerian root, chamomile, kava, and lavender are promoted as sleep aids, but the evidence for their effectiveness is much less clear.

Sedatives and hypnotics have the advantage of being applicable to a number of situations that might interfere with sleep, such as shift changes, jet lag, or stress-related short-term insomnia. The drugs can help to alleviate these short-term problems and be discontinued to preclude the risk of dependency.

Depending on the specific type of drug class, there are changes in the nature of an individual's sleep, although the significance of these changes is unknown.

It is possible to develop a dependence on hypnotics if used for a long period of time, and there is often a "rebound insomnia" in which sleep is slightly worse for 1 or 2 nights after discontinuing the drug even if used for only short periods of time.

If the drug is a particularly long-acting one, or if the individual has high sensitivity, there may be a "hangover" effect the next day when the individual may feel sluggish or show sleep inertia. Sleep inertia or actual inability to wake up while on hypnotics largely precludes their use during operations.

Hypnotics should be used only by prescription from a physician and only for as long as necessary to "get over the hump" of sleeplessness, and this should be at the lowest clinically indicated dose for as short a time as possible. Hypnotics are an aid to achieve sleep schedule readjustment, not a preferred means for getting sleep over the long run.

Stimulants

Stimulants exert a physiological effect on the nervous system so that the effects of sleep loss can be temporarily reduced. Caffeine (discussed in a previous subsection) is an example of a stimulant, one that does not require a prescription and that does not have any significant adverse side effects unless consumed in very large quantities.

Stimulants are particularly useful to the relatively small population of individuals who suffer from narcolepsy or other debilitating sleep disorders. Military personnel sometimes use stimulants during sustained operations, under controlled conditions and supervised by a flight surgeon.

The effects of prescription stimulants such as dextroamphetamine and modafinil are clear-cut: alertness is increased and performance is enhanced, relative to sleep-deprived individuals. These effects are also observed to some extent with a number of over-the-counter decongestants containing pseudoephedrine and with herbal stimulants such as ephedra.

Synthetic stimulants such as amphetamine and modafinil are controlled substances and should be used only under the guidance of a physician for treatment of a specifically debilitating sleep disorder.

Herbal stimulants are unregulated, and the effects of many are unknown because of lack of proper evaluation. However, it is known that ephedra, in particular, is associated with heart attack and stroke. All herbal stimulants should be considered as unproven and a safety hazard. Decongestants are not designed for increasing alertness; this happens as a side effect, along with increased drying of mucous membranes.

Even under the guidance of a physician, stimulants can have unwanted and potentially dangerous side effects, including changes in blood pressure and pulse, headaches, irritability, appetite loss, insomnia, nervousness, talkativeness, and sweating. Extreme reactions include hallucinations and paranoid psychosis.

Prescription stimulants are not generally permitted for operators of public transportation vehicles in the United States and many other industrialized nations. Randomized drug testing is regularly carried out to cut down on the use of most known stimulants, at the threat of loss of job. These prohibitions may also apply to certain job categories in highway construction.

Most stimulants have a high potential for addiction and abuse because of the rapid euphoria that results from high doses. This can lead to a cycle of binging and crashing, and long-term abuse can lead to mental and behavioral disorders.

Finally, possession and use of controlled substances without a proper physician's prescription is illegal and could result in fines and jail time.

Effectiveness

Hypnotics and stimulants have demonstrated effects on sleep and alertness. Due to the controlled nature of these substances and the potential for legal problems and abuse, the team does not recommend systematic application in the highway construction environment.

Highway Construction Environment Implementation

Discussion of hypnotics and stimulants is usually a part of fatigue training in other domains, when discussed in conjunction with medical issues such as sleep disorder screening. Individuals should be encouraged to seek sleep disorder screening if they believe they have a problem or if management notices specific fatigue-related job performance issues.

15. Model-Based Schedule Optimization

This countermeasure involves using knowledge of physiological processes controlling sleep and alertness to predict worker level of fatigue on the job.

Type of Countermeasure: Preventive

Level of alertness at any particular point in time is controlled by three basic factors: (1) circadian rhythm, (2) prior sleep and wake history, and (3) length of time awake. Specific alertness values can be predicted from knowing where individuals are in their circadian phase, when and how long they slept during the past few days, and how long it has been since they most recently awoke. This conceptualization conforms to biology and common sense: an individual is naturally sleepy toward the late evening hours, sleeping recovers alertness, and alertness decreases the longer an individual is awake.

It is possible to use the general nature of these models to predict how an individual is likely to be feeling during a schedule change, and through continued schedules such as night shifts and weekend closures. For example, if a worker is going to switch from day to night shifts, it is likely that he will wake up on the 1st day of the night shift at his usual time, for example, 7:00 a.m. By the time he goes to work at 11:00 p.m., his alertness profile will be at the circadian high point, making it initially easier to stay awake, even though he would be habitually going to bed at this time. As he stays awake throughout the night, his alertness will decrease as it follows the circadian rhythm process; there will be no increased value on his sleep recovery process to balance that out, and the recovery sleep that is obtained will be curtailed because it is during the day.

Using knowledge of how alertness is affected by internal physiology can help individual workers and schedule planners to anticipate how much fatigue crews will have at certain points in time and to think about potential countermeasures they might use, such as caffeine, a nap, or, to the extent possible, schedule adjustments that will promote adaptation.

Alertness models are useful to estimate periods of reduced alertness so that specific countermeasures can be identified and used. Additionally, alertness profiles from the models can be used to design fatigue-avoiding work schedules.

There are many other variables contributing to momentary alertness levels, such as stimulation level, other countermeasures employed, and individual differences in sleep need. Therefore, model predictions should be used as guidelines rather than as absolute predictors of alertness. This is not really a limitation; model predictions can effectively be used to compare different schedule options to see which one is the most fatigue-avoiding option and to identify the best times to deploy fatigue countermeasures.

Research with application of models in specific industrial settings has shown that there tends to be resistance to adopting model recommendations, a circumstance which is predominantly due to a lack of training in how to interpret model predictions correctly. Models, like other tools, should be used with proper training on their inputs, interpretation of results, and appropriate uses. This training does not need to involve a major time commitment, but without any training personnel can misunderstand model predictions, leading to bad scheduling or countermeasure decisions and subsequent distrust of the modeling tool.

Effectiveness

Fatigue models are effective for estimating risk of impairment under various schedules, can guide countermeasure application and timing, and can serve as an educational tool for understanding fatigue and its impacts. The limited evaluations of fatigue modeling in operational environments suggest that adoption and diffusion are limited at this time and that organizational and work practice barriers may impede broad adoption.

Highway Construction Environment Implementation

Scheduling tools are used in highway construction, but primarily by designers and engineers to develop task sequences for construction and for contractual compensation. Even the largest projects appear to be relatively “low-tech” when it comes to safety training and worker scheduling. They are performed more on the basis of standard practice and construction schedule needs than on consideration of worker fatigue, although this does come into play over the long term. Construction projects that use software for worker scheduling could include fatigue prediction as an additional scheduling criterion at a relatively low investment cost, making model-based schedule optimization a promising technology for the near future.

16. Fatigue Risk Management System (FRMS)

An FRMS is a comprehensive program for addressing worker fatigue that is a component of an overall safety management system.

Type of Countermeasure: Preventive

The concept of FRMS has evolved with the advances in fatigue science, modeling, and theories of organizational risk and error. Fundamentally, an FRMS is part of a "defense in depth" strategy for addressing a broad range of safety issues within an organization. FRMSs are meant to be part of a safety culture and to provide a flexible means to address fatigue that is an alternative to prescriptive hours-of-service rules.

The fundamental elements of an FRMS are shown in Figure 3.5.

Key elements of such a program include incident reporting, including voluntary reports by workers and crew; monitoring of fatigue-related information (such as reports and safety trends); modeling and assessment of work schedules; and tracking of related information such as absenteeism. Education and training programs are a fundamental part, as is a steering committee of actively involved staff to keep the system functioning.

FRMSs have been implemented in a number of industries with round-the-clock operations, primarily transportation.

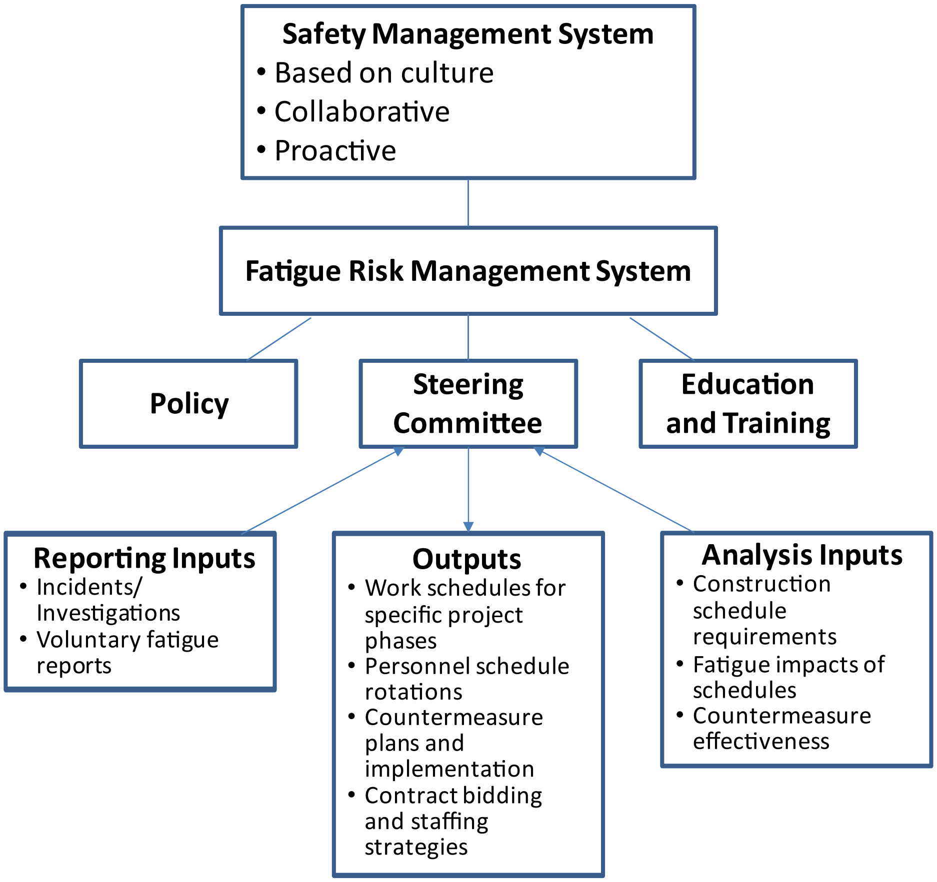

Figure 3.5. *Integrated elements of a Fatigue Risk Management System.*
Source: Adapted from Gander et al. 2011.

Effectiveness

The effectiveness of FRMS is unknown, in terms of overall impact of fatigue-related safety problems. Evaluation data concerning education are mixed, and there is one study suggesting a positive trend of increased sleep in personnel participating in an alertness management program. Other evaluation studies report increased awareness of fatigue, but also problems related to organizational change and acceptance. There are no set criteria or regulatory standards for developing or evaluating FRMS program content or for monitoring the effectiveness of its implementation. Transport Canada, however, has developed extensive toolkits for FRMS development in transportation that can be easily adopted for other settings.

Highway Construction Environment Implementation

Safety programs and training seem to be the province of a single individual even in the very large programs, and the personnel and organizational infrastructure and the knowledge base for developing an FRMS, or for properly evaluating consultant offerings, do not appear to be available.

Instead of moving to a full FRMS at this point in time, the team recommends that contractors and states adopt a more practical approach to fatigue management by drawing on the various tools that are already available, such as training, countermeasures, and alertness modeling. These tools could initially be tailored to individual contractor needs, although the team foresees the prospect of an industry association offering standardized materials and approaches that address the range of highway construction environments.

17. Worker Status Monitoring and Alerting Technologies

Type of Countermeasure: Operational

Alertness monitoring involves tracking the performance or physiological measures of workers to determine if they are approaching drowsiness or impairment. Operator status monitors seek to measure and record, in real time, some physical or physiological features of the operator's eyes, face, head, heart, brain electrical activity, brain blood flow, muscular activity, reaction time, and so forth. Embedded measure technologies compare current operator state on some aspect of performance on the task at hand, such as lane deviation or steering variability in a vehicle.

Virtually all of these technologies are in the research stage. There is no research on how to best warn (alert) when a degraded state of impairment or drowsiness is detected. While some devices may be commercially available, there is not yet sufficient evidence about their reliability, validity, and effective use to warrant routine implementation.

These are some of the questions that remain to be answered:

- What are "normal" versus safety-critical "abnormal" values for the measures generated by the device?
- What constitutes acceptable performance for operators on a given task? Alternatively, are downward trends or gradual performance degradation seen?

- Could a perfectly safe operator be classified as "unacceptable" on occasion (e.g., score a false positive)?
- What measures are best for providing an "early warning" so that operators have not already gone too far into the impairment zone?

Suitable answers to these and other questions must be developed for each monitoring technology and for workers in each mode of operation.

Effectiveness

Although some reliability has been shown in laboratory situations, technological status monitoring for worker fatigue has not been effectively implemented in operational settings. Workers tend to find the technologies obtrusive.

Highway Construction Environment Implementation

This approach does not yet warrant consideration for implementation in the highway construction environment.

18. Bright Light or Melatonin for Circadian Shifting

Type of Countermeasure: Operational

The use of bright light as an operational fatigue countermeasure refers to timing workers' exposure to outside or bright indoor light in order to shift the circadian rhythm to correspond to a new work schedule or to acutely enhance alertness.

Melatonin is a hormone produced by the pineal gland in the brain that is secreted during the evening and night hours. Synthetic or natural melatonin is used in high doses to induce sleepiness, adjust the circadian rhythm to new schedules, or both.

Bright Light

One reason that shift workers are sleep deprived is that their circadian rhythms do not adjust from that of a day-oriented worker because of the constant exposure to day-oriented time cues such as bright light and social activity. Bright light can be used in several ways to help overcome fatigue:

- Bright light exposure in the evening shifts the circadian rhythm to a later time, such that maximum drive for alertness shifts from the evening to the night.
- Bright light exposure in the early morning shifts the circadian rhythm to an earlier time, such that maximum drive for alertness shifts from the evening to the afternoon.
- Day-to-day bright light exposure carefully adapted to the shifting circadian rhythm can result in further shifts to later or earlier times as desired.
- Bright light exposure at any time of day also results in an acute alertness boost, which lasts as long as the light exposure continues.

Achieving the desired effect from bright light, to adapt to a new work schedule for example, requires careful planning of the time of administration, knowledge of the present state of the circadian rhythm to figure this out, and avoiding bright light at times when it is not supposed to be administered. In practice, therefore, only the acute alerting effect of bright light can be effectively achieved. There may, however, be side effects of unintended circadian shifts that may make it difficult to readjust to a normal schedule, for instance after a weekend closure with much nighttime bright light exposure.

Use of light exposure for resetting the circadian rhythm is a complex undertaking and should be guided by a person knowledgeable in circadian physiology. Additionally, the benefits of resetting the circadian rhythm can be maintained only through fairly rigid adherence to the procedure and ensuring that other time cues (e.g., daylight) are minimized. That is, in addition to light exposure, it is also important to control the timing of darkness. This is especially true for those workers who may be traveling between work and home in the bright morning sun. In these cases, it is important to minimize exposure to the sunlight by wearing dark glasses (special goggles are recommended).

Melatonin

Melatonin in pharmaceutical doses (0.3 to 5 mg) has fairly rapid sleep-inducing effects and lowers alertness and body temperature. When combined with proper timing and managed light exposure, melatonin can help workers to adjust to a new schedule by shifting the circadian rhythm.

Like bright light, melatonin can be used in several ways to help overcome fatigue:

- Taking melatonin in the evening shifts the circadian rhythm to an earlier time, such that maximum drive for sleep shifts from the night to the evening.
- Taking melatonin in the morning shifts the circadian rhythm to a later time, such that maximum drive for sleep shifts from the night to the morning.
- Taking melatonin day-to-day in a way carefully adapted to the shifting circadian rhythm can result in further shifts to earlier or later times as desired.
- Taking melatonin at a time of day when sleeping is normally difficult opens the gate for sleep.

Note that the circadian rhythm-shifting effects of melatonin work in the opposite direction of those of bright light.

The timing of melatonin is an important factor; it needs to be taken in the proper relationship to the body's biological rhythm in order to achieve the desired effect. Using melatonin to delay the circadian rhythm is especially complicated because of the interaction with daylight, which is a more powerful adaptation mechanism. As with bright light, use of melatonin for resetting the circadian rhythm is a complex undertaking and should be guided by a person knowledgeable in circadian physiology. Additionally, the benefits of resetting the circadian rhythm can be maintained only through fairly rigid adherence to the procedure and ensuring that other time cues (e.g., daylight) are controlled.

The Food and Drug Administration does not regulate the sale of melatonin, so the quality of products available in health food stores and other outlets is uncertain.

Because melatonin can cause drowsiness, it should not be taken if an individual intends to drive or engage in other complex or potentially dangerous activity.

The sleep-inducing effects of melatonin are temporary, so while individuals may be able to fall asleep at an unusual time by using melatonin, they may not be able to stay asleep for as long as desired. Additionally, various side effects of melatonin have been reported, including worsened fatigue, depression, coronary artery constriction (possibly increasing heart attack risk), and possible effects on fertility. For these reasons, melatonin should be used only under the guidance of a properly trained physician.

Effectiveness

Both bright light and melatonin have been shown, under proper circumstances, to facilitate readjustment of the circadian rhythm. Light also has an acute alerting effect, which is, however, transient. These countermeasures are difficult to deploy effectively and reliably in an operational environment; thus, they are not considered effective for the highway construction environment.

Highway Construction Environment Implementation

Bright light and melatonin are not recommended for use by highway construction contractors or state agencies. Individuals may seek medical advice regarding their application, but these measures should not be generally promoted by the organization.

4

FATIGUE RISK MANAGEMENT SCHEDULE GUIDANCE AND WORK PRACTICES

HOW TO USE THE GUIDANCE IN THIS SECTION

This section contains work schedule guidance and work practice recommendations for the range of shift schedules commonly encountered in rapid renewal construction. The guidance consists of fatigue models for each basic work schedule type (Day Shift, Night Shift, Weekend Closure, Switching Shifts, Manager and Designer), typical schedule variations for a few basic types, and both preventive and operational fatigue countermeasures tailored for each work schedule type. These shift profiles and countermeasures are intended as guidance only; they are meant to provide managers with information to make decisions about specific work assignments and for planning overall construction schedules to balance worker fatigue management with project schedule goals. There is no one-size-fits-all solution for a project or for an individual worker. This guidance is intended to assist managers in achieving a balance between project objectives and worker fatigue management.

MODELING SUMMARY AND WORK PRACTICE GUIDANCE IMPLICATIONS

This section discusses the most significant work practices for fatigue management, such as scheduling decisions, shift start and stop times, closure lengths for various construction phases, and specific fatigue countermeasure implementation within a schedule. The technical basis for these recommendations can be found in the technical report for this project, *Identifying and Reducing Workforce Fatigue in Rapid Renewal Projects*.

Daytime Construction

Daytime construction schedules are preferable as a means of minimizing fatigue and obtaining adequate recovery sleep. Models of daytime construction schedules (40 to 60 h per week) show no differences in fatigue profiles across shift type or throughout the week, assuming 7.5 h sleep per night. Fatigue level peaks in the early afternoon and rises again sharply just before bedtime. In practice, however, fatigue is likely to increase as shifts get longer. The longer the shift, the less off-duty time is available for daily tasks (e.g., personal care, parenting, household chores), and sleep may be sacrificed to accomplish these.

Nighttime Construction

Nighttime construction schedules of all variations show fatigue levels substantially higher than day schedules due to reduced sleep opportunity based on circadian pressure for wakefulness during the day (see Figure 4.1 for an example). Fatigue rises continuously throughout the night-shift work period and the commute home, peaking at bedtime (about 1 h after arriving home, in the team's models). Furthermore, nighttime construction schedules of all variations show a cumulative fatigue effect because reduced sleep hampers recovery (as in Figure 4.2 and, especially, Figure 4.3).

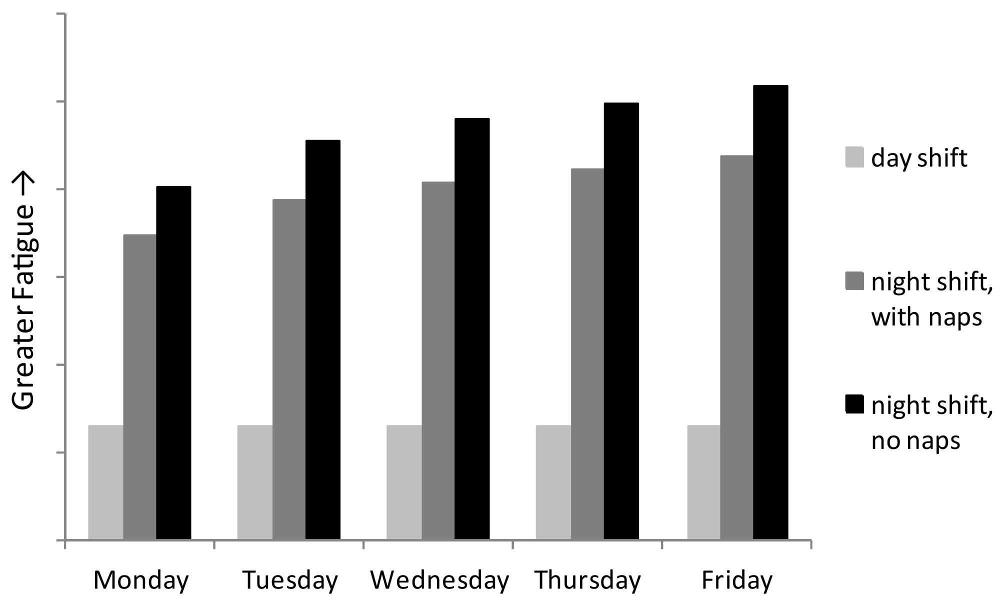

Figure 4.1. *Peak fatigue: 5 × 10 (50-h week) day shift and night shift with and without naps.*

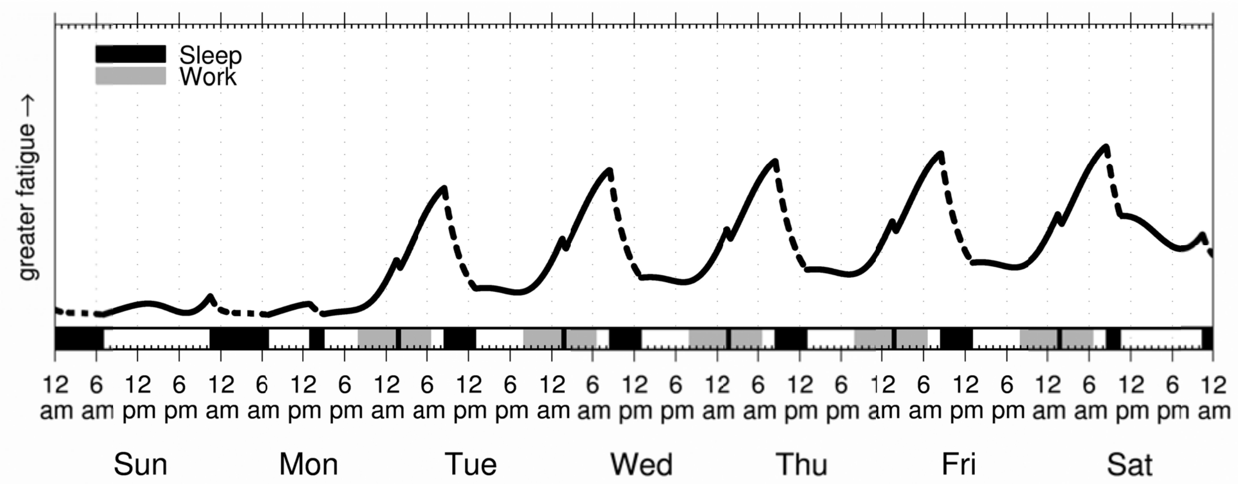

Figure 4.2. *Fatigue profile: 5 × 10 (50-h week) night shift with mid-shift and defensive naps.*

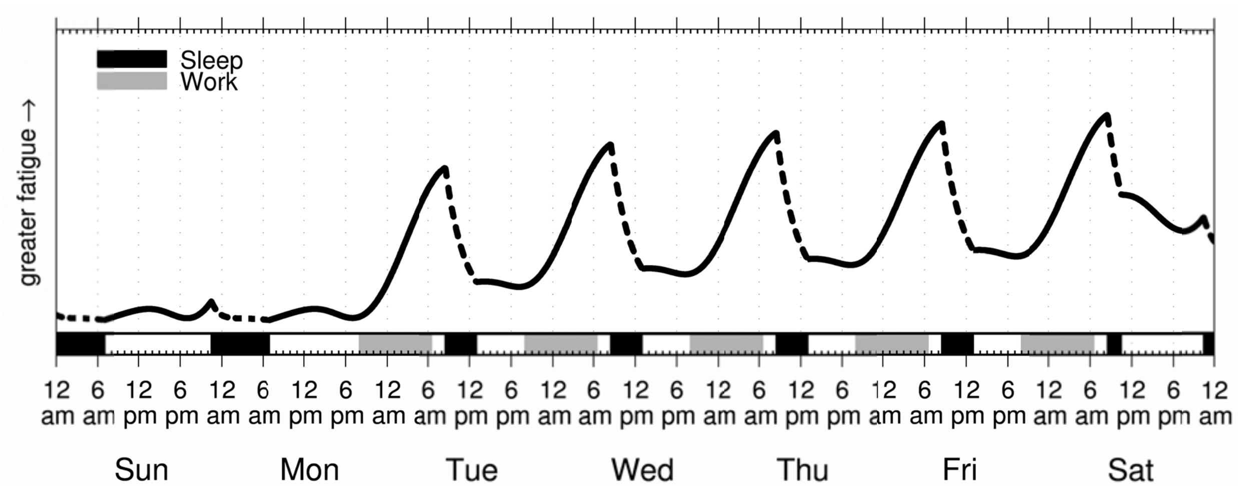

Figure 4.3. *Fatigue profile: 5 × 10 (50-h week) night shift without naps.*

Fatigue in night schedules is exacerbated by later work stop times and can be reduced through earlier stop times, such as a 4:30 a.m. stop (Figure 4.4). Extended night shifts (10 h or more) tend to end later than shorter shifts and can result in severe sleep restriction (5 h or less) due to circadian pressure to wake around 1:00 p.m. For this reason, extended shifts should not be used on a regular basis for the same crew.

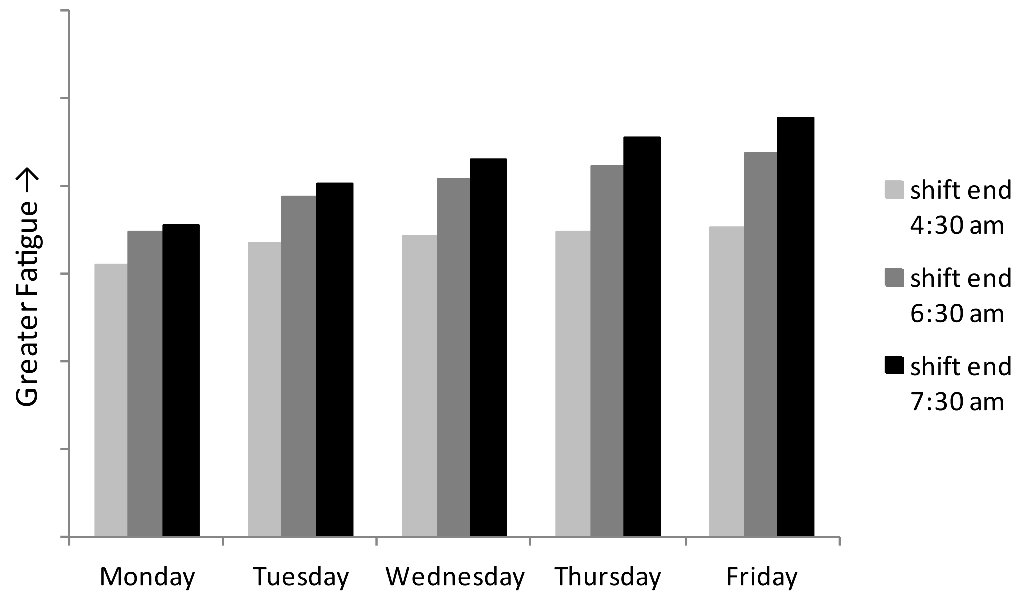

Figure 4.4. *Peak fatigue: night shift with various work stop times.*

Taking naps is effective in reducing fatigue while working night shifts. A mid-shift nap on night schedules, even when of short duration (30 min), is the single most effective fatigue countermeasure. It reduces peak fatigue and lowers the cumulative effect across days. A longer defensive nap (2 h) in the afternoon before the first night shift in a week is also helpful in reducing fatigue. Night shifts of any duration are substantially more fatiguing without these naps; a 5 × 10 night shift schedule is used as an example (Figure 4.5).

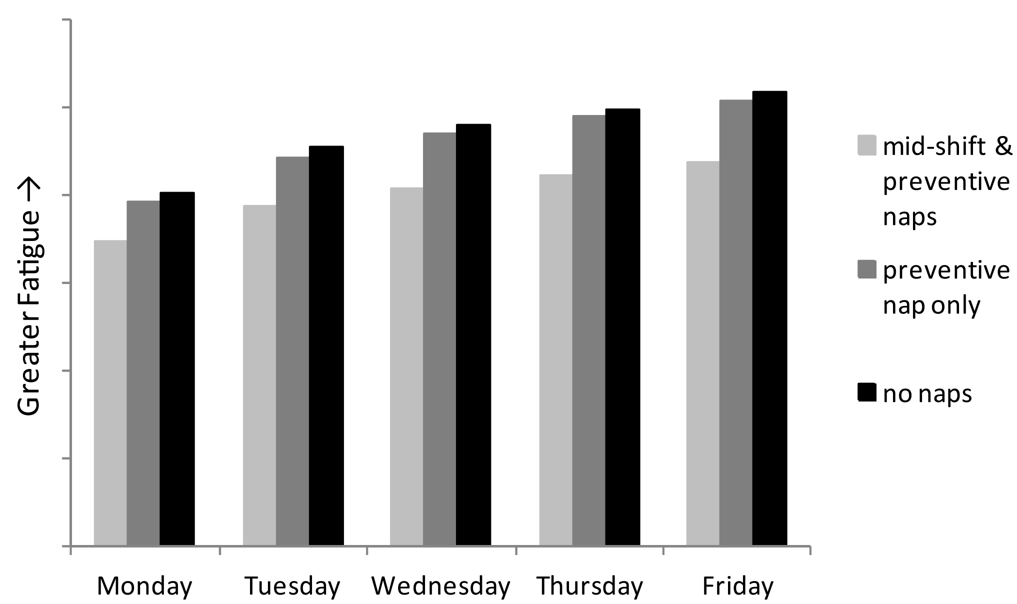

Figure 4.5. *Peak fatigue: 5 × 10 (50-h week) night shift with and without mid-shift and defensive naps.*

In summary, a night-shift schedule organized to accommodate maximum recovery opportunity would end early and allow workers to take naps. Figure 4.6 compares peak fatigue for a typical day shift with "best-case" and "worst-case" night-shift scenarios, the best-case scenario being a shift that ends at 4:30 a.m. and workers take mid-shift naps and a defensive nap, and the worst-case scenario being a night shift that ends at 7:30 a.m. and workers take no naps. The best-case night-shift scenario still results in peak fatigue that is at least double that of a typical day shift. However, by the end of the workweek, the worst-case night-shift scenario results in peak fatigue approaching twice that of the best-case night-shift scenario, as well as a substantially more rapid accumulation of fatigue throughout the week.

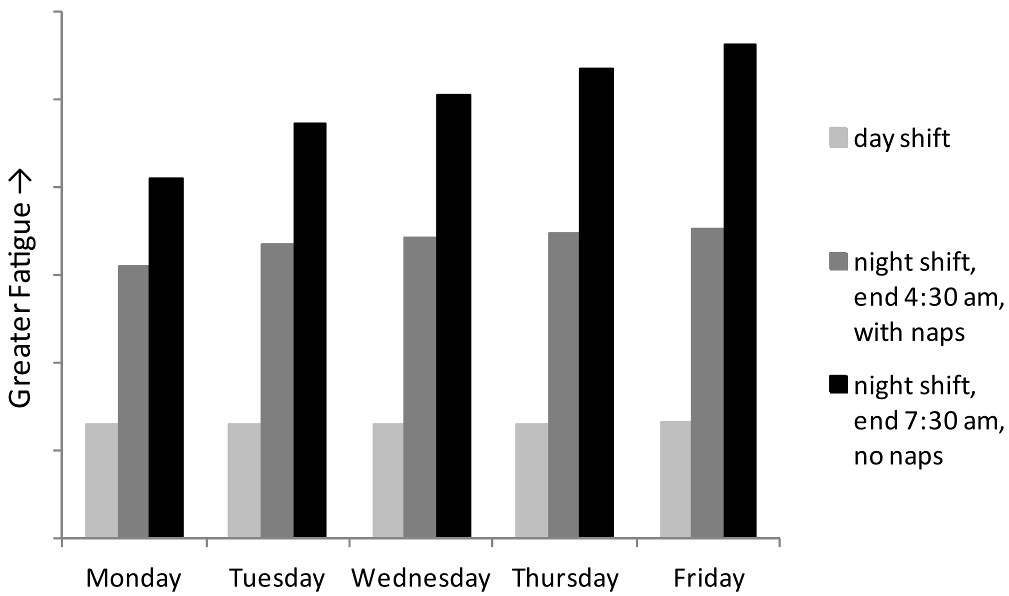

Figure 4.6. *Peak fatigue: day shift versus best-case and worst-case night-shift schedules.*

Finally, the team's fatigue models showed no substantive difference in fatigue levels for night-shift schedules where the worker reverts to a day schedule on days off (sleeping at night following a long morning nap after the last night shift) relative to maintaining a night schedule (sleeping 8 h during the day). However, it may be advantageous for workers to revert to a day schedule on days off, even if they will be returning to a night-shift schedule the following week, for two reasons. First, keeping a more "normal" schedule on days off will allow them to participate in many activities that are difficult while on a night shift, including family and social activities. Second, sleep quality for most individuals is poor during the day, even when the number of hours in bed would seem sufficient for adequate recovery. Little, if any, adjustment of the circadian rhythm to a night-shift schedule is expected unless such a schedule is maintained for many weeks and light and dark schedules can be reversed. Other than indoors on oil platforms and in space, this is usually not feasible (Van Dongen et al. 2011).

Shift Switching and Weekend Closures

Granting workers a day off (i.e., a full 24 h between the end of one shift and the start of the next) when switching from a night-shift schedule to a day-shift schedule (or vice versa) is preferable to using double shifts or shifts with a very short break in-between. This is true for both midweek shift switches and for short-term shift switching that occurs as a result of a weekend closure. For example, when workers who are usually on day shift are chosen to cover night shifts for a continuous weekend closure, a full 24-h break at each switch provides the best recovery opportunity.

Managers and Designers

Managers wishing to maintain high levels of on-site presence during weekend closures can reduce fatigue by engaging in two separate sleep periods ("anchor sleep" or "split sleep"): a longer one of at least 4 h at night (the anchor sleep period) and a shorter period of 2.5 to 3 h (a supplemental nap) during the day (Mollicone et al. 2008). A manager the team interviewed reported his work and sleep periods during a recent weekend closure, and using this as a model, the team constructed an anchor sleep schedule that would have allowed the same number of hours at work with regular presence on site during both day and night shifts. Peak fatigue could be reduced considerably using the alternative, anchor sleep schedule (Figure 4.7).

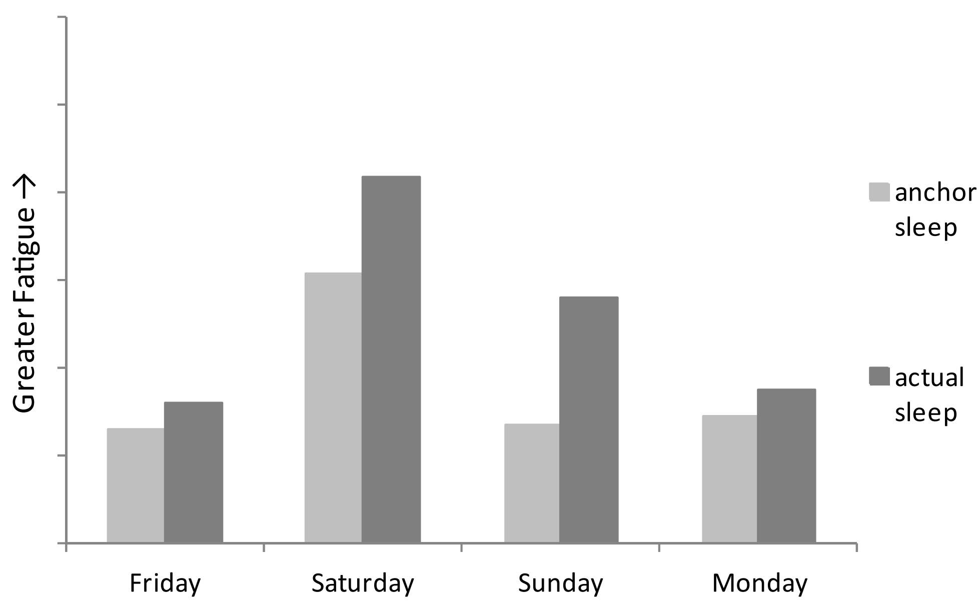

Figure 4.7. *Peak fatigue: manager's actual versus possible anchor sleep schedule for 55-h weekend closure.*

Designers (or engineers) working high-production schedules of 80+ h per week are vulnerable to cumulative sleep reduction and increasing fatigue. Fatigue levels are higher than for a standard day shift due to substantially reduced sleep opportunity while working very long (up to 14 h) days, and peak fatigue increases gradually throughout the week (Figure 4.8). Tactical countermeasures such as strategic naps and self-selected breaks can reduce the immediate impacts, but this type of schedule should not be sustained.

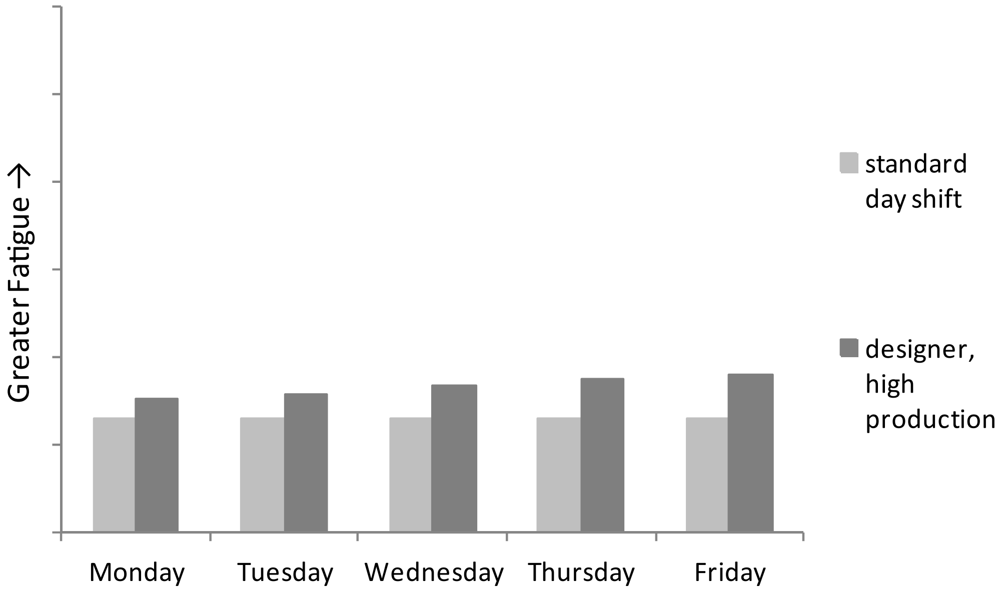

Figure 4.8. *Peak fatigue: high-production designer/engineer schedule versus typical day schedule.*

Restricted Sleep

A single night of sleep restriction leads to increased fatigue on the day shift for several subsequent days, and 2 nights lead to even greater fatigue (Figure 4.9). Acute sleep restriction (sleep loss) can occur for many reasons, including illness, household pressures, or emotional stress. Recovery frequently takes more than a single full night of sleep.

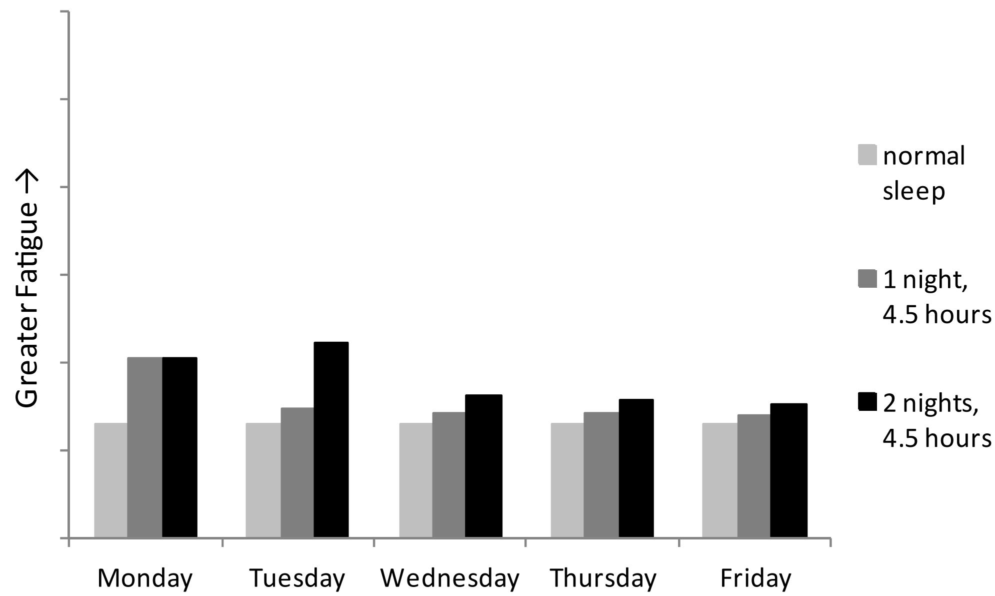

Figure 4.9. *Peak fatigue: day shift with normal sleep (7.5 h per night) and 1 and 2 nights restricted sleep (4.5 h).*

Daytime construction schedules with unusually early start times (e.g., 6:00 a.m.) or long shift durations (e.g., 12 h) may result in curtailed sleep periods. Increased fatigue can be avoided by taking naps at mid-shift or after work. After-work naps should begin before 6:00 p.m. to avoid the circadian high-alert period that begins in the early evening. If naps are not used to alleviate excess fatigue, the peak fatigue trajectory of such a worker will be similar to that of high-production designers (Figure 4.8).

Caffeine Use

Caffeine can be used effectively before and during a shift for relief from acute fatigue. Caffeine is most effective when used sparingly; on day shift, it is most useful in the morning and during the "post-lunch dip" in early afternoon. Consumption should cease at least 5 h before bedtime, though there are large individual differences in caffeine impact.

Sleep inertia experienced upon waking from mid-shift naps may be counteracted with consumption of a caffeinated beverage before the nap, which will take effect as the nap is ending (Reyner and Horne 1997; Van Dongen et al. 2001). This may be particularly useful on night shift, when workers may be concerned about their ability to awaken fully from a mid-shift nap. A cold, rather than hot, caffeinated beverage may facilitate rapid consumption prior to the nap.

Table 4.1 provides a structured comparison of the schedules and countermeasure variations modeled, the major fatigue findings, and work practice implications.

TABLE 4.1. STRUCTURED COMPARISON OF THE SCHEDULES AND SCENARIOS MODELED, THE MAJOR FATIGUE FINDINGS, AND WORK PRACTICE IMPLICATIONS

Scenario	Major Fatigue Findings	Work Practice and Countermeasure Approaches
Day Shifts	• No substantive fatigue differences across week or shift types • Fatigue increases to mid-afternoon, declines toward evening, increases before bedtime	• Caffeine during day, but no later than 4:00 p.m. • Maintain consistent sleep and wake times throughout the week if possible • Maintain similar or identical sleep and wake times on weekend or non-work days • Strategic naps (on the job) to reduce impact of restricted sleep • Consume caffeine just before strategic naps to counteract sleep inertia on waking • Self-selected rest breaks to reduce fatiguing impacts of monotonous tasks or highly complex tasks
Night Shifts: 5, 7, 8, 11-h closures	• Sleep durations significantly shorter than day shifts because of circadian rhythm influences: 3.5 to 6.5 h due to circadian pressure to wake around 1:00 p.m. • Mid-shift nap substantially reduces peak fatigue within and across shifts and reduces cumulative effects	• Minimize use of extended shifts (10 to 12 h) due to reduced individual crew recovery opportunities • Caffeine during shift, but no later than 5 h before bedtime • Consider returning to day schedule (sleeping at least 8 h per night) on days off, following a morning nap on 1st day off from nights • Sleep in on the weekend to make up for sleep loss during the week • Strategic naps (on the job) to reduce impact of shortened sleep periods • Consume caffeine just before strategic naps to counteract sleep inertia on waking • Defensive nap in the afternoon before beginning night shift • Self-selected rest breaks to reduce fatiguing impacts of monotonous tasks or highly complex tasks • Supervisory monitoring for signs of fatigue and application of countermeasures
Weekend Closure: 55 h	• Modeling shows same effects as day and night shifts above • Field data suggest increased fatigue among day-shift personnel in week following closure • Managers may feel they need to maintain a presence on the job site for as much as possible of the closure weekend; fatigue can accumulate during night shifts	• Consider selective half or full day off after closure to provide recovery opportunity • Anchor ("split") sleep schedule (nighttime anchor sleep and daytime nap) for managers to obtain 6 to 8 h in two separate sleep periods • Avoid double shifts • Use countermeasures appropriate for shift worked, as described above

continued

TABLE 4.1. STRUCTURED COMPARISON OF THE SCHEDULES AND SCENARIOS MODELED, THE MAJOR FATIGUE FINDINGS, AND WORK PRACTICE IMPLICATIONS (CONTINUED)

Scenario	Major Fatigue Findings	Work Practice and Countermeasure Approaches
Switching Shifts	• Modeling shows same effects as day and night shifts	• Avoid double shifts • Use countermeasures appropriate for shift worked, as described previously
Manager and Designer	• Designers working high production can exceed 80+ h per week	• Reduce high-production designer workload through increased staffing and project planning • Same countermeasures as for day shifts
Restricted Sleep	• Schedules regularly leading to 6.5 h sleep or less nightly will result in cumulative fatigue • Sleep restricted to 4.5 h or less per night on 1 or 2 nights will result in increased fatigue levels, and this short-term sleep loss can affect fatigue long term • In either case, fatigue level is higher than fatigue levels for standard extended day-shift schedules	• For persons with consistently shortened sleep periods, a daily nap timed to avoid circadian high points (mid-shift or immediately after work) each workday will help maintain fatigue at low levels and supplement the main sleep period • For individuals with acute fatigue from short-term sleep loss, sleep in on the weekend or take naps when able to make up for sleep loss during the week • Same countermeasures as for day shifts

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