U.S. Department
of Transportation

Federal Railroad
Administration

1200 New Jersey Avenue, SE
Washington, DC 20590

DEC 19 2011

Mr. Michael Flanigon
Inspector-in-Charge
National Transportation Safety Board
490 L'Enfant Plaza SW
Washington, DC 20594

Dear Mr. Flanigon:

Fatigue has been a long-term problem for the railroad industry and needs to be continually addressed as we learn more about the underlying fatigue indicators and the effects of fatigue on performance. The effects of fatigue have a serious impact on railroad safety. For this reason, the Federal Railroad Administration (FRA) has funded and continues to fund studies looking at the effects of fatigue on performance.

I have enclosed two reports that discuss FRA's research efforts in the area of fatigue. The first is a white paper authored by FRA's Office of Research and Development titled "The Railroad Fatigue Risk Management Program at the Federal Railroad Administration: Past, Present and Future." This paper, published in 2006, highlights many of the research efforts undertaken by FRA in the past 15 years.

The second paper, "Fatigue and Alertness in the United States Railroad Industry, Part II: Fatigue Research in the Office of Research and Development at the FRA" details the fatigue research goals of FRA. Additionally, this paper presents information on the feasibility, utility, and cost effectiveness of fatigue management efforts of the government, unions, and the railroad industry. The paper also provides a plan for the transfer of technology and knowledge between interested groups.

In addition to these two publications, enclosed is a list of some newer FRA-sponsored fatigue research efforts with links to download full text for FRA-published documents.

Furthermore, resources such as educational fatigue and alertness materials have been created, and as we gain more understanding of how fatigue affects performance, new resources are being developed. Once such effort, the North American Rail Alertness Partnership (NARAP) was developed as a joint effort between rail labor, management, and FRA to provide educational information on managing fatigue and increasing alertness.

FRA has used information from these and other studies to help inform the updates made to the Hours of Service Act. FRA understands that the problem of fatigue is greater than what can be solved only though amendments to Hours of Service and continues to conduct research and fund railroad industry pilot projects looking at innovative fatigue management practices. For one such effort, FRA is working with the Research and Innovative Technology Administration's Volpe Center on the Web site, "The Railroaders' Guide to Healthy Sleep." The Web site is designed to provide locomotive engineers, conductors, and other safety-critical personnel with educational information about sleep disorders, access to an at-home screening questionnaire for sleep apnea, information on how to obtain treatment for sleep disorders, how lack of sleep and circadian misalignment affect performance, and how railroad personnel can get the sleep they need. I anticipate the Web site will be available to the public in early 2012.

Currently, FRA is in the process of drafting guidance for railroads to develop Fatigue Management Plans (FMP) as part of a larger railroad safety risk reduction program. Taking into account the multifaceted nature of fatigue, these FMPs will be designed to reduce fatigue through appropriate countermeasures, scheduling practices, employee education, and increased opportunities for rest. FRA hopes that the development of these FMPs will lead to a reduction in the amount of fatigue experienced by railroad employees and, ultimately, increase railroad safety.

FRA is in the final stages of drafting two documents related to fatigue. The first provides information related to developing Fatigue Risk Management Systems in the rail industry. The second document will provide information to the passenger rail industry regarding fatigue mitigation strategies and the development of FMPs.

Fatigue continues to be a safety concern and more can and should be done to address fatigue issues and increase railroad safety. Programs such NARAP, and the development of FMPs, rely on all of us working together to gather necessary information, identify research needs, and continually improve and refine these programs to better address safety needs.

Looking forward, FRA will continue to identify research needs and gaps, develop educational materials, identify new mitigation strategies and technologies, and sponsor rail industry pilot projects in an effort to increase our understanding of fatigue and its underlying mechanisms.

Sincerely,

[redacted]

Ron Hynes
Acting Deputy Associate Administrator
for Safety Compliance and Program Implementation

Enclosures

Enclosure 1

FRA-Sponsored Fatigue Research Efforts
(Links to Full Text Provided for FRA Published Documents)

Gertler, J. and Nash, D. (2004). *Reducing Railroad Dispatcher Fatigue with Alternative Work Schedules* (DOT/FRA/ORD-04/01). Washington, DC: U.S. Department of Transportation.
http://www.fra.dot.gov/downloads/Research/dispatcher_fatigue.pdf

Gertler, J., and DiFiore, A. (2011). *Work schedules and sleep patterns of railroad train and engine service employees in passenger operations* (DOT/FRA/ORD-11/05). Washington, DC: U.S. Department of Transportation.
http://www.fra.dot.gov/rpd/downloads/TR_Work_Schedules_and_Sleep_Patterns_final.pdf

Hursh, S.R., Raslear, T.G., Kaye, A.S., & Fanzone, J.F. (2006). *Validation and calibration of a fatigue assessment tool for railroad work schedules, summary report* (DOT/FRA/ORD-06/21). Washington, DC: U.S. Department of Transportation.
http://www.fra.dot.gov/downloads/Research/ord0621.pdf

Hursh, S.R., Raslear, T.G., Kaye, A.S., & Fanzone, J.F. (2008). *Validation and calibration of a fatigue assessment tool for railroad work schedules, final report* (DOT/FRA/ORD-08/04). Washington, DC: U.S. Department of Transportation.
http://www.fra.dot.gov/downloads/Research/ord0804.pdf

Raslear, T. G., Hursh, S. H., and Van Dongen, H. P. A. (2011). Predicting cognitive impairment and accident risk. In Hans P.A. Van Dongen and Gerard A. Kerkhof, (Eds.), *Human Sleep and Cognition, Part II: Clinical and Applied Research. Progress in Brain Research, Vol. 190.* Amsterdam: Elsevier. pp. 155-167

Sussman, E. D., and Raslear, T. G. (2008). Railroad human factors. In D. A. Boehm-Davis (Ed.), *Reviews of Human Factors and Ergonomics, Volume 3.* Santa Monica, CA: Human Factors and Ergonomics Society. pp. 148-189.

Tabak, G. and Raslear, T.G. (2010). *Procedures for validation and calibration of human fatigue models: The Fatigue Audit Inter-Dyne Tool* (DOT/FRA/ORD-10/14). Washington, DC: U.S. Department of Transportation.
http://www.fra.dot.gov/rpd/downloads/TR_Procedures_or_Validation_and_Calibration_final.pdf

The Railroad Fatigue Risk Management Program at the Federal Railroad Administration: Past, Present and Future

The National Rail Safety Action Plan, announced by former Secretary Mineta in May 2006, calls for the Federal Railroad Administration (FRA) to "address the serious problem of fatigue among railroad operating employees". Embodied in this plan was the specific objective to "Accelerate research on railroad crew work history to validate a fatigue model for possible use to improve crew scheduling." This white paper is in response to the mandate of the Secretary and provides a synopsis of past and present actions taken by the FRA to manage the risk of fatigue in the railroad industry and outlines plans for future actions.

The Past

The FRA has, historically, managed the risk of fatigue in the railroad industry through enforcement of the Hours of Service Act of 1907 as amended through 1989. The current HOS law (49 U.S.C. §21101 *et seq.*) stipulates that train service employees may work no longer than 12 continuous hours followed by a minimum of 10 hours off duty, and that they be given at least 8 consecutive hours off duty in every 24-hour period. Consequently, an individual can work 11 hours and 59 minutes, be off duty for 8 hours, and return to work at the end of that 8-hour period. Moreover, such a pattern could continue for many consecutive days, so that the individual's work schedule would never develop a consistent circadian pattern. Crew members are generally called approximately 2 hours before reporting time, so that the maximum duration of uninterrupted sleep could be between 6 and 7 hours. However, since the required 8 hours off-duty time includes commuting, leisure and personal time, the duration of any sleep would be even less than that. Further, actual periods of work, which may include traveling in "deadhead" status to a work site, waiting on a train for transportation and traveling back to the point of final release, can greatly exceed 12 hours. Furthermore, as noted by the National Transportation Safety Board (NTSB) and other concerned parties, the statutory maximums and minimums are not based on science.

The FRA is the only modal administration within the Department of Transportation whose HOS are mandated by Congressional statute and, therefore, may not be adjusted or modified by administrative procedures. Thus, FRA is restricted in its efforts to aggressively initiate an appropriate range of fatigue mitigation measures. This limitation on FRA's administration authority has resulted in an environment wherein:

A commercial airline pilot can fly up to 100 hours per month;

A truck driver can be on duty up to about 260 hours per month;

Shipboard personnel, at sea, cannot operate more than 360 hours per month, and only 270 hours per month when in port; and

Locomotive engineers can operate a train up to 432 hours per month, which equates to more than 14 hours a day each of those 30 days.

(Testimony of Chairman Hall, NTSB, before the Committee on Transportation and Infrastructure, Subcommittee on Railroads, House of Representatives, April 29, 1998).

This raises the question: "Is the HOS law sufficient to prevent fatigue in the railroad industry?" Two FRA-sponsored empirical studies in the 1990's indicate that the answer is "No".

Pollard's (1996) work/rest diary survey of 200 locomotive engineers found that while the average locomotive engineer obtained only 20 minutes less sleep than the average person, locomotive engineers who started work between 2200 and 0300 hours averaged only about five hours of sleep. There is considerable variation in the amount of sleep that locomotive engineers obtain, depending on the time of day when work starts, because human physiology enables sleep at night but makes sleeping during the day difficult.

Thomas, Raslear and Kuehn (1997) also found that locomotive engineers in a simulator study, working strictly within the FRA HOS, accumulated a progressive sleep debt over a period of days. Engineers working a 10-hour shift with 12 hours off-duty averaged 6.1 hours of sleep, while engineers with 9.3 hours off-duty averaged only 4.6 hours of sleep. The engineers reported a progressive decrease in subjective alertness across the duration of the study, and performance of safety sensitive tasks degraded during the same time period. Thomas *et al.* concluded that FRA HOS law allows work schedules that degrade job performance and reduce the safety of railroad operations. Again, a law that merely allows time for sleep is not sufficient to ensure adequate sleep, prevent fatigue and maintain safe rail operations.

Based on these and other studies, it is now widely acknowledged that while HOS restrictions are necessary to establish limits on the amount of work that individuals are allowed to perform, they are not sufficient to prevent fatigue.

Since human physiology cannot be altered, any 24/7 operation will have some fatigue risk associated with it. The question remains, "What is the contribution of fatigue to the risk of human factor accidents in the railroad industry?" Current research, discussed below, will help answer that question.

The Present

Fatigue risk in a 24/7 operation is not just about how much work (hours per day) is performed, but also about when (time of day) that work is performed and for how many consecutive days it is performed. HOS regulations typically address how much work is performed. An effective proactive fatigue risk management program needs to balance the amount of work performed against when the work is performed, how long a work schedule is in effect, and several other variables. While some of these factors may be capable of a regulatory solution, past research has already established that time of day influences are intractable, and the effective regulation of the other factors requires information that has only recently become available through FRA-sponsored research.

Several data collection and research activities now provide a quantitative picture of the role of fatigue in railroad accidents that was previously unavailable. For example, the Fatigue Avoidance Scheduling Tool (FAST) has now been validated and calibrated (Hursh, Raslear, Kaye and Fanzone, 2006). FAST is a biomathematical model that can be used to assay the risk of fatigue in work schedules and to plan schedules that ameliorate fatigue. The model takes into account the time of day when work occurs (circadian rhythm) and opportunities for sleep based on work schedules. The model validation used work histories from 400 human factors and 1000 non-human factors accidents. FAST was used to calculate cognitive effectiveness[1] (the inverse of fatigue) from the 30 day work histories prior to the accidents and at the time of the accidents. The data are from 2003, 2004 and the first six months of 2005.

The data from Hursh *et al.* showed that there is a reliable relationship between the time-of-day of human factors accidents and the expected, normal circadian rhythm. This circadian pattern was not reliably present for non-human factors accidents. The risk of a human factors accident is increased by 20% by working during the hours from midnight to 3 AM.

Hursh *et al.* also showed that there is a reliable linear relationship between effectiveness and the risk of a human factors accident. This relationship accounts for 86% of the variance in the data. In contrast, there is not a reliable relationship between effectiveness and the risk of a non-human factors accident.

Hursh *et al.* showed that there was an elevated risk of human factors accidents at any effectiveness score below 90, and accident risk increased as effectiveness decreased. Effectiveness scores below 70 were associated with a reliable increase in human factors accident risk, but not in non-human factors risk. The risk of a human factors accident is increased by 21% at effectiveness scores at or below 70. Twenty three percent of the accidents examined occurred at or below an effectiveness score of 70. Based on other research, an effectiveness score of 70 is the rough equivalent of a 0.08 blood alcohol level or being awake for 21 hours following an 8-hour sleep period the previous night. There is a 65% increase in human factors accident risk at an effectiveness score of 50 or less.

[1] Cognitive effectiveness is a metric that tracks speed of performance on a simple reaction time test and is strongly related to overall response speed, vigilance, and the probability of lapses (Hursh, S.R., Redmond, D.P., Johnson, M.L., Thorne, D.R., Belenky, G., Balkin, T.J, Storm, W.F., Miller, J.C., and Eddy, D.R. (2004). Fatigue models for applied research in warfighting. *Aviation, Space and Environmental Medicine*, *75*, 3, Suppl.: A44-53.; Van Dongen, H.P.A. (2004). Comparison of mathematical model predictions to experimental data of fatigue and performance. *Aviation, Space and Environmental Medicine*; *75*, 3, Suppl.: A15-36.).

Hursh *et al.* found that cause codes associated with accidents that occurred at or below an effectiveness score of 70 showed an over-representation of the type of human factors accidents that might be expected of a fatigued crew (e.g., signals passed at danger). Property damage from all the human factors accidents examined was estimated to be approximately $46,000,000. Of this amount, human factors accidents with effectiveness scores at or below 70 account for approximately $18,000,000, or 39%, of property damage.

Other FRA analyses of accidents agree substantially with the Hursh *et al.* results. The time-of-day of severe accidents from the Switching Operations Fatality Analysis (SOFA) study (August 2004 Update) shows a reliable relationship to the expected, normal circadian rhythm. The circadian rhythm accounts for 22.6% of the variance in the time-of-day of these accidents. Since this data set includes all severe accidents, *regardless of cause*, from 1997 to 2003, this estimate of the strength of the circadian influence in accidents is entirely consistent with the estimate in Hursh *et al.*[2]

The Collision Avoidance Working Group (CAWG) examined 65 main-track train collisions in which human factors causes contributed to trains exceeding their authority by passing a stop signal, failing to comply with a restricted speed signal, or entering territory without authority. CAWG found that 19 of the 65 accidents (29.23 %) involved impaired alertness (defined as failing to take appropriate actions to avoid the accident). In the Hursh *et al.* accident sample, 37.6% of similar accidents had effectiveness scores of 70 or below. Nearly all of the 19 CAWG collisions occurred between midnight and eight AM, which indicates a strong circadian effect. FAST was used to independently corroborate that fatigue was a contributing factor in these accidents.

In the June 28, 2004 accident at Macdona, Texas, involving a collision between a Union Pacific Railroad train and a BNSF Railway Company train, three persons died, 30 persons were injured and nearly $ 6 million in damage occurred. Using FAST, FRA determined that train crew fatigue was a contributing factor in the accident. The NTSB in its report NTSB/RAR-06/03 of July 6, 2006, agreed with the findings of the FRA, and also included other possible factors as related to the accident.

Work/rest diaries from representative samples of signalmen (see also), maintenance-of-way workers (MOW), and dispatchers have been collected, and a preliminary analysis of data from the first two groups is complete. While this data will be extensively analyzed with FAST in the near future, a preliminary analysis discloses some interesting patterns consistent with the Hursh *et al.* findings.

For instance, while 39 % of U.S. adults get less than 7 hours of sleep on workdays, 66 % of MOW workers, 64 % of signalmen and 55 % of dispatchers have this amount of sleep. This is roughly consistent with the pattern seen by Hursh *et al.* for

[2] Assuming 6% of the variance for 1000 nonhuman factors accidents and 51% for 400 human factors accidents, the weighted average, *regardless of cause*, would be 23.3%).

locomotive crews[3]. Sixteen percent of MOW workers and signalmen, and 19% of dispatchers get less than 6 hours of sleep on workdays. Although this diary data has not been analyzed with FAST, it can be roughly estimated that workers getting less than 6 hours of sleep for 7 consecutive days would have an effectiveness score of less than 63 if they were working at 4 AM. If the impact of reduced effectiveness is the same for these populations as for the locomotive crews studied in Hursh *et al.,* their accident risk would be elevated by 21 to 39 %.

The need to address fatigue issues with regard to medical conditions is also a component of the National Rail Safety Action Plan. On November 15, 2001 an accident between two Canadian National/Illinois Central Railway trains resulted in the fatalities of two crewmembers and serious injuries to two others. The NTSB in its report, NTSB/RAR-02/04, of November 15, 2001 stated that the primarily cause of the accident was the obstructive sleep apnea of two crewmembers. Recommendations were made to the Canadian National Railway and FRA to address obstructive sleep apnea and other medical conditions impacting upon the performance of an employee. FRA's Safety Advisory 2004-04, "Effect of Sleep Disorders on Safety of Railroad Operations", was issued on September 21, 2004 in response to the NTSB's recommendations. Two studies recently sponsored by FRA address fatigue concerns from the perspective of sleep disorders and depression. The findings of these studies will be available in 2007. The Railroad Safety Advisory Committee is also developing medical fitness-for-duty standards and procedures that will address sleep disorders.

The Future

FAST is a validated and calibrated tool for quantifying fatigue in the railroad industry. FAST or similar tools should be used to quantitatively evaluate and implement fatigue management plans in the industry.

For instance, although fatigue countermeasure programs have been widely implemented in the industry over the past six years, this has been done without concern to properly evaluate the effect of these programs. In most instances, the programs have been terminated for economic reasons. Future fatigue management implementations must have support to allow an adequate *a priori* examination of the likely success of the planned countermeasure and an evaluation plan to demonstrate its effect when implemented.

As noted above, most countermeasure programs have been terminated for economic reasons. This has been done in the absence of solid economic data concerning the cost of fatigue in railroad accidents. The FRA will provide this economic data by analyzing the property damage, loss of life and injuries associated with the 400 human factor accidents in the Hursh *et al.* study. A business case for fatigue management will be made on the basis of this and associated analyses.

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[3] Locomotive crews spend 65% of their work time above an effectiveness level of 80. This is consistent with obtaining less than seven hours of sleep each day during a work week.

A cadre of the Office of Safety's inspector force has received training on the use of FAST during accident/incident investigations. The data derived from the incorporation of FAST into investigation protocols will provide invaluable information for establishing fatigue mitigation measures based upon operational demands and work/rest schedules.

The database used by Hursh *et al.* will be published so that other biomathematical fatigue models can be validated and calibrated. The databases from work/rest diary studies will also be published to allow further exploration of fatigue issues by other researchers.

While the current HOS law provisions pertain to "on-duty" time, a number of fundamental issues are not covered by the law and require the attention of FRA if human factors accidents are to be reduced from the current level of approximately thirty-five percent and the safety and quality of life of the industry's employees are to be substantially improved. First, is the recognition that time off from work is equally important as time "on-duty." Second, time of day and its impact on the circadian rhythm of employees must be fully understood. Third, an awareness of the medical factors that influence fatigue, e.g., sleep disorders, depression, stress, etc. needs to be addressed in a more expeditious manner. Finally, the FRA must continue its efforts to develop educational and training information that provides the industry's stakeholders an awareness of what constitutes fatigue and what remedies are available. (Plans for establishment of a website are presently underway). All these factors are within the realm of the FRA. However, their resolution depends on the acceptance of the scientific principles of fatigue and the incorporation of these principles in the development, implementation and monitoring of work/rest schedules through the *collaborative efforts* of all industry stakeholders.

There are factors that are not within the control of FRA, such as the provisions of collective bargaining agreements that pertain to working hours and pay (mileage stipulations). However, through the sharing of scientific knowledge and experience in fatigue management, future agreements can be structured to reduce human factors accidents due to fatigue.

Office of Research and Development
Office of Safety
November 2006

ELSEVIER SCIENCE Ltd. [DTD 4.1.0]
JOURNAL TRF ARTICLE No. 48
PAGES 1-8 DISPATCH 15 January 2001

TRF 48

PROD. TYPE: FROM DISK

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TRANSPORTATION RESEARCH PART F

PERGAMON

Transportation Research Part F 000 (2001) 000–000

www.elsevier.com/locate/trf

Fatigue and alertness in the United states railroad industry part II: Fatigue research in the Office of Research and Development at the Federal Railroad Administration

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Received 1 September 2000; received in revised form 4 December 2000; accepted 18 December 2000

Abstract

The Federal Hours of Service Act of 1907, which regulates the US railroad industry, imposes both maximum work hours and minimum rest periods. However, this act does not limit employees' weekly or monthly work hours, restrict the irregularity or unpredictability of on-call work schedules, or restrict mandatory commuting distances without compensatory time off. Extensive night work, irregular work schedules, extended work periods with few or no days off, and the policies, procedures, and agreements that encompass these work scheduling practices, all evolved within the limited provisions of this act. It is not clear, though, that broad changes in the hours of service laws are the answer to these problems. Consequently, the Office of Research and Development at the Federal Railroad Administration, with its Fatigue Research Program, has embarked upon a non-prescriptive approach to better manage fatigue in the railroad industry. This program includes the development and implementation of improved fatigue data collection methodologies, better measurement and evaluation tools, and more effective fatigue countermeasure strategies. The North American Rail Alertness Partnership (NARAP) has become an important means for understanding the fatigue-related problems in various operational settings, and for identifying specific programmatic areas that will better meet the needs of the industry. The program goals of improving the feasibility, utility and cost effectiveness of fatigue management are to be realized with the cooperative efforts of the government, unions, and the railroad industry, particularly though NARAP, and by broadly disseminating important technical findings through journal publications and conference proceedings.

Keywords: Railroad; Fatigue; Alertness; Shift work; Work schedules

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1369-8478/00/$ - see front matter
PII: S1369-8478(01)00006-7

1. Background

The Conference theme of non-prescriptive approaches to managing fatigue in transportation would normally present a unique challenge to government researchers, who work within a regulatory framework that requires scientific and technical support for its rulemaking activities. Fortunately, a new approach for improving safety in the US railroad industry was initiated in the 1990's by the Federal Railroad Administration (FRA) under the administration of Joline Molitoris. As stated in a recent report by the General Accounting Office (1997), "Rather than citing violations and civil penalties as the primary means to obtain compliance with railroad safety regulations, FRA has emphasized *cooperative partnerships* with other federal agencies, railroad management, labor unions, and the states."

One of the outcomes of this new partnering approach to safety is the North American Rail Alertness Partnership (NARAP). As outlined in its charter, the purpose of North American Rail Alertness Partnership charter (1998) is "to support industry-wide initiatives through the coordination, facilitation, and communication of efforts to reduce fatigue and promote safety in rail operations" and "to promote the safety of the industry's employees by developing effective countermeasures, based upon analytical and/or scientific data" (North American Rail Alertness Partnership strategic plan, 1997). NARAP members include key government, labor and management officials, who meet on a quarterly basis.

FRA's Office of Research and Development (OR&D) has embarked upon a Fatigue Research Program. This program will systematically assess the many underlying factors that result in fatigue and reduced alertness, and develop appropriate tools that will assist the industry in developing its own effective fatigue management solutions. The program goals of enhanced alertness and performance are to be realized through FRA's cooperative approach with labor, management, and other government agencies, in particular NARAP. The OR&D also expects to accomplish its program goals by broadly disseminating important technical findings. Three areas of research are needed to better understand fatigue problems and to help foster effective fatigue management programs in the US railroad industry: (1) fatigue data collection, (2) valid and reliable fatigue measurement and evaluation tools, and (3) fatigue countermeasure strategies.

2. Fatigue data collection

As in most industries, consistent and reliable data on fatigue (particularly good exposure data) is often lacking in the railroad industry. For example, a recent study, entitled Switching operations fatalities analysis (in press), indicated that fatigue could not be investigated as a contributing factor to fatalities because the relevant data was missing, incomplete, or lacked good exposure measures for establishing appropriate rate information. Even though this study involved nearly two years of cooperative effort from management, labor, government and other human factors researchers, no definitive conclusions on fatigue-related fatalities could be established. Another preliminary study conducted by Foster–Miller, found FRA's accident/incident database useful for determining overall trends, but is limited in its usefulness for determining principal factors involved in incidents and injuries. Despite this, fatigue-related incidents are generally considered to be much more prevalent than the data suggests (Sussman & Coplen, 2000).

2.1. Incident data and incident investigation methods

Because there is limited fatigue-related data available for conducting good quality statistical analyses, the FRA is planning to modify its incident reporting system to include fatigue-related factors. The FRA is also planning to modify its incident investigation methods and training to recognize fatigue as a possible contributing factor to incidents. OR&D plans to provide the required technical support needed for developing standardized fatigue data to be collected during incident investigations. OR&D also plans to provide the necessary technical support for the development, design and utility testing of software tools needed for reliable and consistent collection of fatigue-related data.

2.2. Near-miss data

Efforts are also underway to evaluate the feasibility of developing a near-miss incident reporting system in the railroad industry. For every actual incident, many more near-miss incidents occur. With a much larger data set assumptions can be minimized, additional analyses can be conducted, and results can be interpreted with a greater degree of confidence. Although the FRA already requires the collection of near-miss data related to the safety conduct of locomotive engineers (Title 49 Code of Federal Regulations. Part 240 Section 309); fatigue-related analyses of this data set have not been conducted. Such data could be assessed by using tools such as those mentioned in the Section 3.3. This type of analysis could potentially indicate if there is any relationship between fatigue (determined from the pattern of work from the prior seven days) and near-miss occurrence. OR&D is planning to evaluate the validity of available software programs that analyze fatigue as a possible contributing factor to both near-miss data and incident data.

2.3. Work schedule data

OR&D has begun a project to develop a database of railroad work schedules so that ergonomic assessments and comparisons of different work schedules on fatigue and performance can be conducted. This project will also provide important categorical information that can be included in any modifications to the incident reporting system.

2.4. Other fatigue data

Event recorders are the "black boxes" on locomotives that record most performance activity, including speed, throttle position, dynamic braking, air braking, etc. It is possible that these devices may be a useful source of data for evaluating the effects of different pilot projects on fatigue. To date, however, no known studies have utilized this method of data collection for evaluating the effectiveness of the field interventions currently being implemented by the industry. OR&D will review the capability and practicality of this methodology for collecting fatigue-related data and evaluating the effectiveness of field intervention strategies.

OR&D collects other fatigue data using a variety of research methods to build a broad base of knowledge on fatigue and its relationship to operational performance. Some of these methodologies include structured interviews, surveys, focus groups, work/rest activity diaries, wrist actigraphs, meta-analysis, naturalistic observations, Cognitive Task Analyses (CTA), and literature reviews.

OR&D has compiled a comprehensive bibliography of scientific research on fatigue in railroad operations which is available on the FRA website. The website can be found at http://www.volpe.dot.gov/frarnd/rndpubs.htm. This bibliography references only peer-reviewed articles in academic journals or academic books with railroad operating employees as subjects. A literature review is being conducted on the impact of extensive travel and commuting times on fatigue and performance in non-operating personnel. A bibliography of this literature will also be available on the above website.

3. Fatigue measurement and evaluation

A systems approach for measuring and evaluating fatigue and its effects on *operational performance* is also needed. Research is being conducted in four major areas to develop valid and reliable tools that can aid in the measurement of fatigue and its effects on operational performance: (1) cognitive workload, taskload and performance modeling, (2) job analysis and staffing analysis, (3) work schedule evaluation, and (4) locomotive simulator experiments.

3.1. Cognitive workload, taskload and performance modeling

Good predictive models of cognitive workload/taskload are needed to aid in the measurement of fatigue and to evaluate its effects on alertness and performance. Predictive models will also help evaluate the effects of changes in system states and enable "what if" type questions to be asked, so that fatigue and other performance-related problems can be anticipated before they arise. Using these models, basic principles can be developed for systematically evaluating the effects of changing technology on operator performance and fatigue. These models and procedures for using them would then be made available to the industry.

It is important to use formalized methods, such as cognitive task analyses, to help develop good cognitive workload/taskload models and other decision-making and performance models, which can then be further tested and validated. CTA evolved as a collection of methodologies to enhance human performance by better understanding the cognitive decision-making processes of operations in complex environments, and thereby support the development of computer-based information processing tools. A wide variety of CTA techniques are often employed, including specific knowledge elicitation techniques, function-based task analyses, cognitive work analyses, concept mapping, and conceptual graph analyses. One of the most valuable aspects of conducting a CTA is the systematic documentation it provides on the inherent nature of complex cognitive tasks in operational settings. Therefore, CTAs are an important mechanism for developing measurement and evaluation tools for fatigue and its effects on operational performance.

OR&D completed a preliminary CTA on railroad dispatchers to determine how experienced dispatchers manage trains and control track use (Roth, Malsch, Multer, & Coplen, 1999). The objective was to gain insight into the cognitive demands placed on railroad dispatchers and the decision strategies they have developed in response to those demands. Results of the CTA will be used to develop cognitive workload and performance models of dispatchers. New technology, such as Positive Train Control and other computer-based decision aid systems, can then be evaluated in the dispatching environment for their impact on mediating dispatcher fatigue. CTAs are being conducted for locomotive engineers, maintenance-of-way personnel and other non-operating employees.

On-going studies are being conducted to develop better measures of railroad dispatcher workload, stress, and fatigue, which can also be used in performance and alertness models. The purpose of this project is two-fold: (1) to identify specific job task and work environment factors that contribute to the three variables of workload, stress, and fatigue among railroad dispatchers, and (2) to develop and validate appropriate methodologies for measuring each of these three variables in the dispatching environment. Issues being explored include differences among shifts, traffic volume effects and time of day effects on the level of dispatcher workload, stress, and fatigue.

In addition, a methodology is currently being devised for quantifying dispatcher taskload and objectively evaluating its effects on stress and fatigue. Once validation studies are complete, a PC-based system will be designed to assist in the uniform collection and analysis of taskload data. Such a PC-based system will benefit the industry by providing a ready-to-use electronic mechanism for tracking, monitoring, and evaluating dispatcher taskload. This project has been introduced to the industry at a kick-off meeting with labor and management representatives.

3.2. Job analysis and staffing analysis

Job analysis research is being conducted to identify work practices and work environment conditions that contribute to employee fatigue, injuries and incidents so that remedial actions can be suggested. A preliminary study conducted by Foster–Miller, established appropriate measures for evaluating incidents and injuries for employees on different work schedules and working conditions in yard and terminal operations. Fatigue-related findings suggest that certain yard job and work schedule categories experience significantly higher injury rates than the industry average for all railroad and all yard workers.

An integral component to work schedule evaluation and design is staffing analysis. Various staffing analysis software programs are being evaluated for their possible application to work schedule evaluation and design in the US railroad industry. The goal is to develop a standard methodology for performing an objective staffing analysis in critical operations (locomotive engineers, dispatchers, etc). This staffing analysis methodology will objectively determine minimum staffing levels needed as based on existing criteria. A kick-off meeting was recently held with labor and management to begin this process with dispatchers.

3.3. Work schedule evaluation

OR&D continues to analyze fatigue and alertness data collected with work/rest activity diaries of on-call locomotive engineers (Pollard, 1996). Pilcher and Coplen (2000) evaluated how often and under what conditions locomotive engineers engage in work/rest cycles less than 24 h, and what the effects of those work/rest cycles had on sleep quantity, sleep quality, and self-rated alertness. Further studies are being considered to evaluate the effect of these irregular work/rest cycles on fatigue and performance, including a review of relevant literature.

Various alertness models and fatigue modeling software are also being evaluated for their application to the US railroad industry. Similar to the fatigue modeling software developed in Australia for predicting work-related fatigue associated with specific rosters in the Australian railways (Dawson, Roach, & Baker, 1997; Fletcher & Dawson, 1998), OR&D is developing a conceptual model for a software tool to evaluate work schedule data in the US railroad industry. The goals are to develop an easy-to-use tool that will help railroad managers and workers in the US railroad industry evaluate their own work schedules for their impact on alertness, and to aid in the design of more ergonomic work schedules. This PC software tool would be able to read work and sleep data from a variety of possible sources. It produce predictions about alertness levels over the following 24 h, as well as providing a method for easily producing raster-plot representations and deconstructing work schedule data. A research protocol will be designed to further develop and validate this tool using criteria-based on one or more of available alertness and human-performance models.

3.4. Locomotive simulator experiments

Simulator experiments allow researchers to explore important safety issues that may be impossible in field settings. Simulator research also provides a much higher degree of experimental control. Thus, they are an important component of OR&D's Fatigue Research Program.

In a recent simulator study, Thomas, Raslear, and Kuehn (1997) found measurable decrements in train handling performance in work/rest cycles of less than 24 h. In addition, they also found that these performance decrements were worse when the work/rest cycle was about 20 h in length as opposed to 22 h in length.

Napping is a potential technique for alleviating the impact of sleep deficits resulting from work/rest cycles of less than 24 h. The FRA, with input from a number of international researchers, has designed a study to evaluate the effects of different nap durations on operation performance in an advanced high fidelity locomotive simulator.

Future simulator research is being planned to study the effects of one-person locomotive operations on fatigue and workload, and to evaluate the ability of cognitive displays, digital communications, and other technology applications to mediate fatigue-related performance problems in the locomotive cab.

Aspects of the physical environment impact operator fatigue and alertness. OR&D is in the process of conducting a meta-analysis to investigate the relationship between temperature in the locomotive cab and operator performance. If it is concluded that such a relationship exists, follow-on simulator research will be considered for investigating the impact of this and other aspects of the physical working environment on crew fatigue and performance.

4. Fatigue countermeasure strategies

NARAP identified eight key components for an effective fatigue countermeasure program in its North American Rail Alertness Partnership strategic plan (1997), including: (1) education and training, (2) employee scheduling practices, (3) emergency response requirements, (4) alertness strategies, (5) evaluation of policies and procedures, (6) adequate rest environments, (7) work environment, and (8) implementation strategies. OR&D's Fatigue Research Program provides *technical support* for many of NARAP's on-going strategies and activities. OR&D regularly sponsors speakers at NARAP meetings to help educate its members about fatigue-related research methodologies and current findings. OR&D is also actively involved in the NARAP Non-Operations Subcommittee, and will provide the technical support necessary to help answer the question, "Is there an increased risk of accidents/injuries associated with travel to and from work [in non-operating personnel]?"

A number of other fatigue countermeasure strategies are also being planned or implemented by the FRA. OR&D will be involved in evaluating the effectiveness of different fatigue countermeasure strategies and technologies employed by the industry.

Based on the results of its CTA studies and the development of appropriate models, OR&D may evaluate, and possibly test: Positive Train Control, digital communication systems, advanced information displays, and other cognitive-based information systems for their ability to mediate the fatigue and alertness problems of locomotive engineers and dispatchers. OR&D is also in the process of evaluating various alertness monitoring devices for their ability to predict fatigue problems, and their utility in allowing railroad operating personnel to take preventative measures to mitigate fatigue.

Finally, OR&D is participating in a human factors program initiative by the US Department of Transportation (DOT) to develop and implement tools, methods, and technologies to detect, measure, monitor, and mitigate operator fatigue in various transportation modes. The DOT released a Broad Agency Announcement soliciting proposals from individuals, businesses, academic institutions and other research centers. This solicitation on Operator Fatigue Management Analytic Systems and Technologies to Forecast and Manage Fatigue and Ensure Alertness for Commercial Transportation Operators was published in Commerce Business Daily on June 16, 2000 (Solicitation DTRS56-00-BAA-0007).

5. Conclusions

The Fatigue Research Program in FRA's Office of Research and Development encompasses a broad variety of data collection methodologies, measurement tools, and countermeasure strategies. Improving our methodologies and practices for collecting fatigue-related data will help us better understand the relationship between fatigue and specific work-related factors, such as work schedules, work environment, job task, or commuting. Improving our tools and methods for measuring and evaluating the effects of fatigue on operational performance will help the government and industry better estimate the true costs of fatigue. Locomotive simulator experiments, for example, that track and monitor fuel consumption, emergency brakings, braking frequency, and other operational performance measures, play a critical role in developing and implementing effective fatigue countermeasure strategies. These studies will not only help identify some of the cost factors associated with fatiguing work schedules or work environment, but will also help estimate the cost savings associated with implementing specific fatigue-related countermeasures, such as strategic napping.

In addition, the ability to quickly profile a specific work group or a particular operation, and then reasonably assess its susceptibility to fatigue, will help the government and industry prioritize and devote our resources to those areas that need them the most. The ability to reasonably forecast decrements in alertness and performance for individuals or work groups will help us develop more effective fatigue countermeasure strategies. The overall success of this program hinges not only on the systematic development of better measurement tools and evaluation methodologies, but also on the cooperation and teamwork of industry, government and research professionals alike. NARAP has become an important venue for enlisting these cooperative efforts. With this comprehensive Fatigue Research Program, and the support of NARAP, FRA's Office of Research and Development is committed to play a leading role in developing non-prescriptive approaches to managing fatigue in transportation.

6. Uncited References

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