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.
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> (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.

[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.

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