TechBrief

FEDERAL MOTOR CARRIER SAFETY ADMINISTRATION

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Impact of Sleeper Berth Usage on Driver Fatigue: Final Report

Introduction

Driver fatigue is recognized as a major factor in accidents involving long-haul truck drivers. One way in which long-haul truck drivers decrease their fatigue level is through the use of tractors equipped with sleeper berth units. However even with these units, the quality and quantity of sleep that a driver obtains may not equal what they would receive if they were sleeping at home. With that in mind, the primary goal of this project was to assess the impact that sleeper berth usage has on operator alertness.

Background

To assist the research team in better understanding the issues surrounding sleeper berth usage, ten focus groups were initially conducted with long-haul operators. (Neale et al., 1998a and 1998b). These operators included both for-hire and owner-operators, as well as union and non-union drivers.

The focus groups were held in eight cities across seven states, providing the researchers with a geographically diverse sample of long-haul drivers. Issues that were explored included factors affecting the quality and quantity of sleep that drivers receive in sleeper berths, drivers' physical and mental fatigue while on the road, and other safety-related issues associated with long-haul truck operations where sleeper berths are used.

Insights gained as a result of these focus groups were broken down into two areas, Team Driving and Equipment. The research team learned the following:

- Many drivers can only receive quality sleep in a stationary truck, therefore team drivers should be selected based on their ability to sleep in a moving truck.
- If teaming, drivers should be allowed a voice in selecting their driving partner so that drivers are teaming with someone they trust.
- In addition, both drivers should know what their schedules are far enough in advance so as to allow the drivers to come to a consensus as to who will be driving first. This will allow the partner driving first to prepare by getting adequate sleep prior to departure.
- Team drivers should be equipped with conventional air-ride tractors (as opposed to those that are cabover and/or spring-ride).
- Clean sleeper berths are important for drivers who drive different trucks.
- Better noise insulation is needed between the cab and sleeper berth, as well as the inside and outside of the cab.
- In addition, better thermal insulation is needed for the tractor.
- Dual escape hatches (on both sides of the sleeper) should be present.

Based on this feedback, and in conjunction with an accompanying literature review, specific objectives related to issues of quality and quantity of sleep, environmental variables, types of trips, driver alertness, driving performance, and frequency of accidents, were written. From this point, researchers at the Virginia Tech Transportation Institute (VTTI), the Virginia Tech Department of Industrial and Systems Engineering (VT ISE), and the Harvard Medical School then teamed up to develop the Method and Protocol described below.

The goal of the Federal Motor Carrier Safety Administration (FMCSA) is to reduce commercial vehicle related fatalities, as well as the number of persons injured in commercial vehicle related crashes, by 50 percent by the year 2010.

FMCSA's Research and Technology programs encompass a range of issues and disciplines, all related to motor carrier and bus safety and security. FMCSA defines a "research program" as any systematic study directed toward fuller scientific discovery, knowledge, or understanding that will improve safety and security, and reduce the number and severity of commercial motor vehicle crashes. Similarly, a "technology program" includes those that adopt, develop, test and/or deploy innovative driver and/or vehicle best practices, and technologies that will improve safety and security, and reduce the number and severity of commercial motor vehicle crashes.

Currently, FMCSA's Office of Research and Technology conducts programs in the area of *Driver Safety Performance*, *Commercial Vehicle Safety Performance*, *Carrier Compliance and Safety*, *Safety Systems and Technology*, *Cross-Cutting Safety Initiatives*, and *Security*. The study described in the following Tech Brief was designed and developed as part of FMCSA's Research & Technology Driver Safety Performance Program. The primary goals of this program are to improve the safety behavior of non-commercial drivers in the vicinity of trucks and buses, and ensure that commercial drivers are physically qualified, trained to perform safely, and mentally alert.

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Method And Data Analysis

In the study, two Class 8 tractors were set up with the necessary equipment and then loaned to truck drivers and/or trucking companies to carry their own revenue-producing loads. To ensure that drivers of VTTI's Class 8 vehicles were not stopped by DOT authorities for not complying with Motor Carrier regulations, VTTI obtained Motor Carrier Operating Authority, the apportioned (IRP) plates, and motor fuel tax permits. (It's important to point out that due to legal reasons related to the licensing, permitting, and insurance process, participating drivers represented for-hire companies only; private drivers and owner-operators were not represented in the study.)

Forty-seven males and nine females participated in this study, constituting 13 teams and 30 single drivers. All drivers who participated in this study were recruited from one of four for-hire commercial trucking companies, two that hauled primarily perishable items and used refrigerated trailers, and two that hauled primarily dry goods and used standard trailers. None of the companies had a union affiliation, and the average age of the drivers was 43 years of age, with an average of 13 years of driving experience.

The two VTTI-owned tractors included a 1997 Volvo L4 VN-series tractor and a 1995 Peterbilt 379. Functionally identical instrumentation packages and data collection systems were installed in both trucks. The data acquisition systems that were installed functioned to record four camera views (shown in Figure 1), including:

- The driver's face
- Driving performance information (including steering, lane departure, and braking)
- Sleeper berth environmental data (including noise, vibration, and temperature)
- Subjective alertness ratings, as well as data from the Nightcap sleep system

Figure 1: Four Camera Views

Because the data collection conducted in the Sleeper Berth project was for periods as long as 6 to 10 days (up to 240 hours), recording data continuously was not possible. As such, a method for reducing the bulk of the data without losing information relevant to the goals of the project needed to be devised. It was therefore decided to implement a data collection system based on the occurrence of "critical incidents," and collect vehicle and driver performance data only when specific triggered events occurred.

For purposes of this study, a "critical incident" was defined as a measured variable that exhibited a pre-determined "signature" or exceeded a trigger criterion possibly indicating fatigue, lapses in performance, a safety-related external event, or potentially even hazardous driving behavior.

Assisting in this definition were a series of expected criteria which were used to help determine when a critical incident occurred. The types of triggered events for which the data acquisition system had been programmed included such things as lane and steering deviations. A complete list of the various trigger types and descriptions can be found in Table 1. Whenever one of these "triggers" was detected, the video and computer data from a period of time 1.5 minutes before through 0.5 minutes after the trigger event were automatically saved. The cause, contributing factors, and circumstances surrounding the incident could then be determined via an analysis of the videotape after the event occurred.

Severity of the trigger was also assessed and categorized as being either a "driver error without a hazard present," a "driver error with a hazard present," a "near collision," a "collision," or as being attributable to another driver. Trigger descriptions included information on driver distraction, driver judgment errors, impediments in the roadway, and so forth.

Driver interaction with the data collection system was minimal. The drivers' only required activities were to:

- Indicate when an unusual critical incident (as defined above) occurred by pressing a button located on the dashboard.
- Respond to random inquiries as to their subjective feelings of sleepiness by pressing one of nine buttons on a panel mounted on the dashboard.
- Wear the Nightcap sleep monitoring device before going to sleep.
- Rate their subjective feelings of sleepiness when they woke up by pressing one of nine buttons on a panel mounted in the sleeper berth.
- Fill out two paper-based surveys each day.

Table 1
Trigger Types and Descriptions

TYPE OF EVENT	DESCRIPTION
Steering	Driver turned steering wheel faster than 3.64 radians/sec.
Lateral acceleration	Lateral motion equal or greater than 0.3 g.
Longitudinal acceleration	Acceleration or deceleration equal or greater than 0.25 g.
Critical Incident Button	Activated by the driver upon pressing a button located on the dashboard when an incident occurred that he/she deemed critical.
Lane Deviation	Activated if the driver crossed the solid lane border (Boolean occurrence).
Time-to-Collision	Activated if the driver followed the preceding vehicle at a closing rate of 4 seconds or less.
Perclos	Activated if the Perclos monitor detected that eyes were closed 8.0% of any given one minute period.
Karolinska Sleepiness Rating	Activated if driver subjectively assessed own drowsiness as extremely fatigued/difficult to stay awake (rating of 7 or above on sleepiness scale).
Karolinska Sleepiness Rating, No Response	Activated if the driver did not respond to the Karolinska rating query.
Timed Trigger	Baseline data for which the data collection system triggered randomly every 45 to 75 minutes.
Lane Departure and Steering	Activated if a lane departure (tractor crossed a lane line) was immediately followed by a steering event. Disabled if turn signal was activated.

No other operation of data collection hardware was required of the drivers. However, when they were at home they were also requested to wear the Nightcap sleep monitoring system to collect 2 to 3 nights of home sleep to be used for comparison. Photos of the instrumentation visible to the driver from the driver's seat and Nightcap sleep monitoring system can be found in Figure 2 below.

Results And Discussion

In this study, team drivers were generally very successful at avoiding circumstances of extreme drowsiness. Conversely, single drivers were greatly affected by drowsiness, which in turn, compromised their ability to safely operate their vehicles.

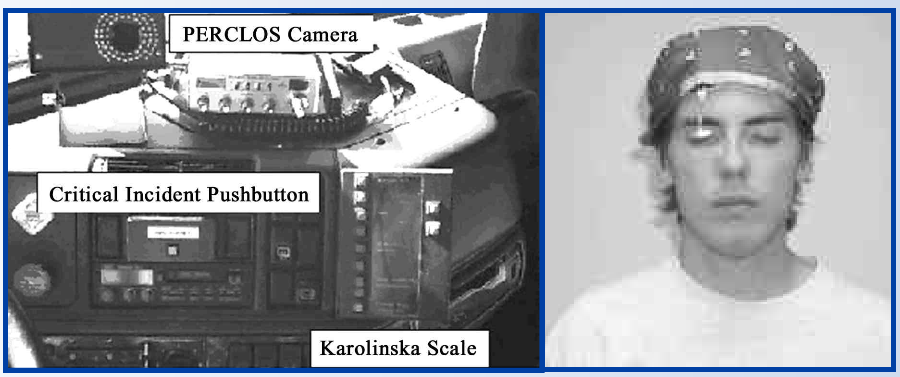

Figure 2: Instrumentation Visible to the Driver from the Driver's Seat and Nightcap Sleep Monitoring System

The benefits of reducing drowsiness are highlighted by the team driving operation. Unlike extremely tired single drivers who may have felt compelled to continue to drive even when it was dangerous to do so, the individual drivers in a team operation generally had no similar compulsion to operate the vehicle when they were extremely tired. From the data collected in this study, it was apparent that the team driving operation translates into fewer bouts of drowsiness, fewer critical incidents, and, in general, safer trucking operations.

In addition, team drivers appeared to drive much less aggressively, make fewer errors, and rely effectively on their relief drivers to avoid instances of extreme drowsiness while driving. In effect, it appeared as though team drivers undergo a natural "screening" process. This was indicated by a number of the truck drivers during the focus groups conducted earlier in this project. Drivers indicated that team drivers must be both considerate of their resting partner and trustworthy with regard to their driving ability. Thus, the level of "acceptance" necessary to be a successful team driver seems to serve as an effective screening criterion.

On the other hand, single drivers in the study had many more critical incidents at all levels of severity as compared to team drivers. Single drivers were involved in four times the instances of "very/extremely drowsy" observer ratings than were team drivers, and were more likely to push themselves to drive on occasions when they were very tired.

In fact, in looking at only the most severe of the critical incidents, more than one-half of the incidents were actually caused by four single drivers.

In terms of hours-of-service violations, based on a report by Wylie et al., (1996), there were relatively few instances (about 2.2 percent) of "extreme drowsiness," with most of these instances being experienced by single drivers, again with a high rate of the occurrence of this level of fatigue on the second or third shift after the first day of a multi-day drive. Thus, it appears that the combination of long driving times and multiple days provides the greatest concern, with several results pointing to the presence of cumulative fatigue. This means that the length of shifts in the later stages of a trip must also be carefully considered.

Having mentioned this concern, it's important to point out that critical incidents and/or driver errors did not increase directly with the hours beyond the regulation. In fact, there was a substantial decrease in the rate of critical incidents during some of the more extreme violations. However, one should exercise great caution when interpreting these results to mean that the hours-of-service should be expanded for the following two reasons:

First, it may be possible that the drivers were making a point to drive more carefully and cautiously because they were operating outside of the regulation and did not want to get stopped by law enforcement officials. Alternatively, they may have only risked driving outside of the regulations because they felt alert and knew that they could continue to drive safely.

Implications

There were a number of findings as part of this study that indicated that the quality and depth of sleep was worse on the road, particularly for team drivers. Team drivers have significantly more sleep disturbances than do single drivers. In addition, for team drivers who sleep while the vehicle is in motion, factors such as vibration and noise affected their sleep, although lighting and temperature aspects of the environment did not appear to be much of a factor.

These findings suggest that while the vehicle was in motion, the noise and motion environment in the sleeper berth degraded the drivers' sleep. This finding has design implications for sleeper berths and indicates that when the truck is in motion, greater attention should be paid to reducing the amount of vibration and noise that invade the sleeper berth. In particular, more effective noise abatement between the cab and the sleeper berth could improve sleep quality, perhaps without much additional cost. Improvement in the vibration/motion environment is a much more difficult problem to address, but also has the potential to improve sleep if proven practical.

It is also important to note that when environmental factors were considered, it was found that many of the sleep disturbances that occurred for single drivers could not be attributed solely to an environmental factor.

Finally, it's worth pointing out that based upon all these results, it is recommended that research in the areas of driver screening/monitoring, driver training, and fatigue management be enhanced. Clearly, if systems and procedures could be developed to identify and either screen or rehabilitate the relatively few drivers that account for the greatest risk in trucking, the potential exists for a large positive impact in the trucking industry.

References

Dingus, TA and Neale, VL, et al, Impact of Sleeper Berth Usage on Driver Fatigue, FMCSA Report No. RT-02-050, Nov. 2001.

Researcher

This study was performed by the Virginia Tech Transportation Institute, 3500 Transportation Research Plaza, Blacksburg, VA 24061. Contract No. DTFH61-96-C-00068.

Distribution

This Tech Brief is being distributed according to a standard distribution. Direct distribution is being made to the Service Centers and Divisions.

Availability

The study final report FMCSA-RT-02-050 is available from the National Technical Information Service (PB2002-107930).

Key Words

Critical Incident, Driver Fatigue, Fatigue, Long-Haul, Sleep, Sleeper Berth, Team Driving

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U.S. Department of Transportation
Federal Motor Carrier Safety Administration

August 2002

Publication No. FMCSA-MCRT-02-070