Log 578A

National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: February 7, 1995

In reply refer to: H-95-5

Mr. Thomas J. Donohue
President and Chief Executive Officer
American Trucking Associations, Inc.
2200 Mill Road
Alexandria, Virginia 22314-5677

A Safety Board analysis of Fatal Accident Reporting System (FARS) data indicates that in 1993 there were 3,311 heavy trucks involved in 3,169 fatal accidents. In these accidents, 3,783 persons died (432 were occupants of the heavy trucks).[1] Research has suggested that truckdriver fatigue may be a contributing factor in as many as 30 to 40 percent of all heavy truck accidents.[2] In 1990, the Safety Board completed a study of 182 heavy truck accidents that were fatal to the truckdriver.[3] These 182 accidents were a census of the heavy truck accidents that were fatal to the driver in the eight States that participated. The primary purpose in investigating fatal-to-the-driver heavy truck accidents was to assess the role of alcohol and other drugs in these accidents. The study found, however, that the most frequently cited probable cause was fatigue. The Board believes that the 31 percent incidence of fatigue in fatal-to-the-truckdriver accidents found in the 1990 study represents a valid estimate of the portion of fatal-to-the-driver heavy truck accidents that are fatigue-related. Little data are available to estimate the incidence of fatigue in the less severe heavy truck accidents.

[1] For this analysis, the Board defined a heavy truck as one >26,000 pounds gross vehicle weight.

[2] (a) Knipling, Ronald R.; Wang, Jing-Shiarn. 1994. Crashes and fatalities related to driver drowsiness/fatigue. Research Note. Washington, DC: U.S. Department of Transportation, National Highway Traffic Safety Administration. November. (b) Ryder, Andrew, ed. 1990. A system in need of overhaul. In: Driver fatigue, Part 1. Heavy duty trucking. September: 69-73.

[3] National Transportation Safety Board. 1990. Fatigue, alcohol, other drugs, and medical factors in fatal-to-the-driver heavy truck crashes. Safety Study NTSB/SS-90/01. Washington, DC.

Because of the significant number of heavy truck-related fatalities and the role of fatigue in such accidents, the Board initiated a study of single-vehicle heavy truck accidents to examine the role of specific factors that affect driver fatigue, such as drivers' patterns of duty and sleep, in heavy truck accidents and to determine potential remedial actions. Most research of the factors associated with fatigue involve laboratory studies that examine the effect of sleep deprivation on the operator's performance of specific tasks, such as controlled driving in which various physiological measures are documented, or involve retrospective reviews of accident records, such as police records, which contain limited data and are not designed to assess the role of human performance factors in fatigue-related accidents. The Safety Board is in a unique position to study the role of human performance factors that contribute to fatigue-related accidents. Accident investigation is the primary function of the Board, and it has been examining the role of human performance factors (and fatigue in particular) in accidents in all transportation modes for many years. Therefore, this study[4] of actual accidents provides a unique opportunity to examine the factors that contribute to fatigue-related accidents.

Because the purpose of the Board's study was to examine the factors that affect driver fatigue and not the statistical incidence of fatigue, the Board specifically selected truck accidents that were likely to include fatigue-related accidents; that is, single-vehicle accidents that tend to occur at night. The Board desired to obtain approximately an equal number of fatigue-related and nonfatigue-related accidents through its notification process to examine the differences between the two groups. From September 1992 through June 1993, the Board was notified by authorities in the States of Alabama, California, Georgia, New Jersey, North Carolina, and Texas[5] of single-vehicle accidents. During this period, the Board accepted sequentially for investigation, with no prejudgment of fatigue involvement, those accidents that occurred within a reasonable driving distance from the Board's regional offices and in which the vehicle was available for examination and the driver was available to be interviewed.

The Board was specifically interested in obtaining accurate information regarding the truckdrivers' duty and sleep patterns for the 96 hours preceding the accident; therefore, the Board limited the accidents to those in which the driver survived and was available to be interviewed by the Board's investigators to reconstruct the previous 96 hours. The Board did not rely solely on the drivers' official log books because of concern that inaccurate or incomplete information might have been recorded and because total sleep time is not required to be reported.

---

[4] National Transportation Safety Board. 1995. Factors that affect fatigue in heavy truck accidents. Volume 1: analysis. Safety Study NTSB/SS-95/01. Washington, DC.

[5] According to FARS data, in 1992 about 27 percent of fatal accidents involving large trucks in the United States occurred in these six States.

The Safety Board investigated 113 single-vehicle heavy truck accidents in which the driver survived. However, because the 96-hour duty/sleep history that was required for the study was not available for 6 drivers, the 6 accidents in which these drivers were involved were not included in the study. The study, therefore, analyzes data from 107 single-vehicle heavy truck accidents.[6]

The Board examined several measures of duty time, driving time, awake time, and sleeping time for the drivers. These measures included (1) the number of hours awake, driving, on duty, and sleeping in the 24-, 48-, 72-, and 96-hour periods before the accident, (2) the number of hours driving since the driver had last slept, (3) the number of hours driving in the period most recent to the accident, (4) the number of hours on duty prior to the accident (including nondriving activities such as loading and unloading cargo, truck inspections, paperwork, calling dispatchers, and waiting at terminals), (5) the number of hours since the driver had last slept, and (6) the number of hours slept in the sleep period most recent to the accident.[7] These measures were taken from the 96-hour logs that were reconstructed from the Safety Board investigators' interviews with the drivers.

The Board also examined the drivers' duty/sleep patterns for the 96-hour period before the accident. The Board established five measures of the drivers' duty/sleep patterns. The five dichotomous (yes/no) measures included irregular duty, irregular sleep, both irregular duty and sleep, regular duty and sleep, and regular sleep with nonclassifiable duty.[8] These five measures are mutually exclusive. The Board also identified three other schedule-related measures that could occur for a driver with either regular or irregular duty/sleep patterns. They include inverted duty/sleep, split sleep patterns, and exceeded hours-of-service limits (exceeded HOS limits).

A total of 21 measures were used to characterize drivers' patterns and amounts of duty and sleep in the 96 hours prior to the accident.[9] Of the 107 drivers, the complete set of duty/sleep measures could not be computed for 20 drivers; hence, data from only 87 drivers were available for analysis (51 were involved in fatigue-related

---

[6] Volume 2 of this study (NTSB/SS-95/02) contains the briefs of the 107 accidents investigated by the Safety Board.

[7] For purposes of discussion in this study, these measures have been termed "duty/sleep time measures."

[8] If a driver did not have at least three consecutive start times, his duty hours were considered "nonclassifiable."

[9] The majority of the single-vehicle accidents in the Safety Board's sample occurred between 2 and 8 a.m. (53 percent), and an even higher percentage of the accidents that were determined to be fatigue-related occurred during these same hours (75 percent). Time of day was not included as one of the 21 measures because of the inherent bias in the sample of cases; that is, single-vehicle accidents are likely to occur at night when traffic is light or sparse.

accidents, 36 were not). As would be expected, the driving and duty times of the 20 excluded drivers were less than those of the 87 drivers who had not had days off. Eleven of the 20 excluded drivers were involved in fatigue-related accidents, and the remaining 9 drivers were involved in nonfatigue-related accidents.

A multiple discriminant analysis[10] was performed to simultaneously evaluate the relationship of a set of 18 predictor measures[11] to the groupings of accidents established by investigators' determination of probable cause (fatigue-related and nonfatigue-related accidents). In the present case, discriminant analysis provides a means of simultaneously examining the capacity of the interrelated sleep, duty, and scheduling measures to classify an accident as either fatigue-related or nonfatigue-related. The combination of measures resulting from the application of the discriminant analysis to the Board's 87 accidents was able to correctly classify 94.4 percent of the nonfatigue-related accidents and 80.4 percent of the fatigue-related accidents—a very high rate of successful classification.[12]

The results of the discriminant analysis indicate that the most critical measures in predicting fatigue-related accidents in the Safety Board's sample are the duration of the most recent sleep period, the amount of sleep in the past 24 hours, and split sleep patterns. It is not surprising that sleep factors rated high in this analysis given the results of extensive scientific research in this area. However, the Board believes that it is noteworthy in this unique sample of actual accidents that factors that affect the ability to obtain adequate sleep, such as irregular duty/sleep and inverted schedules (which are often assumed to be closely associated with fatigue), ranked well below the factors that affect the quantity and quality of sleep.[13]

The truckdrivers in fatigue-related accidents in this sample obtained on average 5.5 hours of sleep in the last sleep period prior to the accident. This is 1.4 hours less than the 6.9 hours they reported needing to feel rested and 2.5 hours less than that obtained by drivers in nonfatigue-related accidents (8.0 hours of sleep in the last sleep period). The findings further indicate that the truckdrivers involved

---

[10] A description of discriminant analysis can be found in the following publication: Tabachnick, B.G.; Fidell, L.S. 1989. Using multivariate statistics. 2nd ed. New York: Harper & Row. 746 p.

[11] Because hours awake and hours asleep in the last 24 or 48 hours were complements of one another, only the time asleep measures were included in the analysis. Similarly, the scheduling measure of regular sleep/duty was not included because it is simply the complement of irregular duty/sleep. Thus, the set of predictors was reduced to 18 measures.

[12] Details of the discriminant analysis are contained in chapter 4 and appendix D of the study (NTSB/SS-95/01).

[13] Although the Safety Board examined single-vehicle accidents, there is no reason to believe that the factors that were associated with fatigue-related single-vehicle accidents would be any different in other kinds of accidents. The Board believes, therefore, that the results of this study can be generalized to the trucking population as a whole.

in fatigue-related accidents obtained about 2.4 hours less sleep in the 24-hour period before the accident than the drivers not involved in fatigue-related accidents (6.9 hours compared to 9.3 hours).

The data indicate that the mean time awake, but not on duty, for the drivers in the fatigue-related accidents was about 5.5 hours. This suggests that these drivers could have readily attained more than the mean of 5.5 hours of sleep during the last sleep period prior to the accident. However, the timing of the awake period may not have fit with the driving schedule to permit 8 hours continuous sleep in the last sleep period. Further, the drivers have a need to attend to family duties and other responsibilities. The fact that drivers in nonfatigue-related accidents also were awake about 5.5 hours while off duty (but still attained 8 hours sleep in the most recent sleep period prior to the accident) suggests that 5.5 hours is not an unreasonable period of time to be allocated to such needs. It appears, therefore, that if the driving or on-duty time is pushed to the maximum hours allowed, drivers will reduce the amount of time for sleep rather than the time needed to accomplish other duties and responsibilities.

Research indicates that the amount of sleep needed varies on an individual basis: "...for some it is 5 to 6 hours a night, for others it is...7 or 8 hours, and for still others it is 9 to 10 hours."[14] The Safety Board recognizes that all truckdrivers do not need 8 hours of sleep. However, responsible public policy dictates that drivers of heavy trucks be able to obtain adequate sleep between work assignments. Implementation of this policy, in the form of Federal regulations or industry procedures and practices, cannot generally address drivers on an individual basis. Thus, implementation of this policy must address the norm, which research has determined to be 8 hours—a fact noted by the ICC in 1937.[15] The results of this study support the need by the "average" driver for 8 continuous hours of sleep.

The Safety Board recognizes that regulations cannot assure that adequate sleep will be obtained. Nevertheless, the regulations can and must provide the opportunity to obtain an adequate amount of rest. However, the 8-hour off-duty requirement in the current regulations does not do so because it does not provide time for travel, eating, personal hygiene, and recreation. Further, depending on various factors, including the time of day, a driver may not be able to fall asleep immediately at the beginning of the 8-hour off-duty period. Because the results of this accident sample are unlikely to be substantially enhanced by any further research, these results provide a solid basis for sound policy decisions. The Board also recognizes that the inadequate sleep obtained may not be directly related to the

---

[14] Dinges, D.F. 1984. The nature and timing of sleep. Transactions & Studies of the College of Physicians of Philadelphia. Ser.5:6(3): 177-206 (p. 198).

[15] (a) Carskadon, M.S.; Dement, W.C. (1994). (b) Carskadon, Mary A., ed. 1993. Encyclopedia of sleep and dreaming. New York: Macmillan Publishing Company.

8-hour off-duty requirement in the HOS regulations. However, in the Safety Board's view, a minimum standard that does not provide for at least 8 hours of sleep is not responsible public policy and could be construed as condoning less than 8 hours of sleep as adequate, when the time needed for eating, hygiene, and recreation is considered. Therefore, the Board is asking the FHWA to complete rulemaking within 2 years to revise 49 CFR 395.1 to require sufficient rest provisions to enable drivers to obtain at least 8 continuous hours of sleep.

Given the results of the latest research and studies on fatigue and sleep issues, the Board believes that steps can be taken now to provide truckdrivers with the opportunity to obtain 8 hours of sleep and that the trucking industry can take a lead role in this effort. Therefore, the Safety Board believes that the trucking industry should incorporate into its scheduling practices and procedures the results of the latest research on fatigue and sleep issues, particularly that an 8-hour sleep need is the norm. The Safety Board believes that current scheduling practices can accommodate a change in the rest period without resulting in undue economic hardships. The Safety Board believes that the majority of trucking companies currently comply with the hours-of-service regulations and that an increase in the amount of off-duty time would not change the way they schedule their deliveries or require changes in the locations of terminals. The data in this sample show that the truckdrivers involved in nonfatigue-related accidents were typically on duty 9 hours a day. These drivers had sufficient time to obtain adequate sleep and, in fact, did obtain 8 hours of continuous sleep in their last sleep period.

The Safety Board recognizes that providing the opportunity to obtain adequate sleep will not assure that drivers actually obtain that sleep. The ICC recognized this in 1937, stating:

> We fully recognize that regulations of this kind cannot provide a complete answer to the problem of driver fatigue and its effect upon safety of operation. We have no control over the manner in which a driver may spend his time off duty, although some of his spare-time activities may tire him quite as much as any work would do. We can only emphasize, by this comment, the responsibility which is the driver's own to assure himself of adequate rest and sleep, in the time available for this purpose, to ensure the safety of his driving, and likewise the employer's responsibility to see that his drivers report for work in fit condition.

Although drivers have a responsibility to obtain adequate rest and sleep, they must first recognize that they need sleep. Many of the truckdrivers in the Safety Board's accident sample who were involved in fatigue-related accidents did not recognize that they were in need of sleep and believed that they were rested when they were not. Drivers in both fatigue-related and nonfatigue-related accidents rated themselves as being okay to fully alert before the accident. Further, about 80 percent

of the drivers involved in fatigue-related accidents rated the quality of their last sleep before the accident as good or excellent. Drivers in fatigue-related accidents received about 1.4 hours less sleep than they reported needing to feel rested. Research has indicated that people "...have a limited ability to predict the onset of sleep...[and that]...subjects certainly do fall asleep at times when they think sleep is highly unlikely."[16]

"Inadequate sleep, even as little as 1 or 2 hours less than usual sleep, can greatly exaggerate the tendency for error during the time zones of vulnerability (1 to about 8 a.m. and 2 to roughly 6 p.m.)."[17] The majority of the accidents in this sample occurred between 2 and 8 a.m. (53 percent), and an even higher percentage of the accidents that were found to be fatigue-related occurred during these same hours (75 percent). Driving at night, as many truckdrivers must do, is complicated by the effects of circadian rhythms. Thus, a sleep deprived person driving at night is in the highest risk situation—a risk that many drivers may not be aware of or recognize.

Modifying the regulations to increase the off-duty period will not, by itself, eliminate the problem of truckdriver fatigue. Educating transportation employees about the effects of fatigue, in the Safety Board's view, is a vitally important component of overall efforts to combat fatigue in transportation. The Board recognizes that there is a considerable amount of research underway that could eventually be used to develop or modify programs designed to educate operators of heavy trucks and other industry personnel, in particular management, about the importance of sleep loss and other factors in fatigue-related accidents. However, the Board believes that this study and other research have provided important information that could be provided now to truckdrivers and management about factors leading to fatigue and possible strategies to combat fatigue. In addition to studies discussed above, the NASA Ames Fatigue Countermeasures Program stands out as demonstrating some especially effective countermeasures. This program, which has been underway since 1980, has addressed strategic napping as a preventive strategy and an operational countermeasure to combat sleep loss, circadian disruption, and fatigue that occur as a result of multiple time zone changes, and extended, irregular duty schedules in flight operations.[18] The researchers found that there is scientific evidence showing that as a preventive strategy, napping before

---

[16] Itoi, A.; Cilveti, R.; Voth, M.; and others. 1993. Can drivers avoid falling asleep at the wheel? Relationship between awareness of sleepiness and ability to predict sleep onset. Washington, DC: AAA Foundation for Traffic Safety (p. 25). 33 p.

[17] Mitler, M.; Carskadon, M.A.; Czeisler, C.A.; and others. 1988. Catastrophes, sleep and public policy: consensus report. Sleep 11(1): 100-109.

[18] Rosekind, Mark R.; Graeber, R. Curtis; Dinges, David F.; and others. 1993. Crew factors in flight operations. IX: Effects of planned cockpit rest on crew performance and alertness in long-haul flight operations. NASA Technical Memorandum 108839. DOT/FAA/92/24. Washington, DC.

fatigue develops is quite effective in an operational setting. A single nap of about 45 minutes in duration prior to a night without sleep can prevent significant loss of performance capability and fatigue throughout the night. The Safety Board agrees that the use of naps as a means to prevent fatigue prior to its onset is a worthwhile countermeasure. The Board cautions, however, that these naps should be a supplement to, not a replacement for, one continuous 8-hour sleep period.

Therefore, the Safety Board believes that the Federal Highway Administration, the Professional Truck Driver Institute of America, the American Trucking Associations, Inc., and the Commercial Vehicle Safety Alliance, and the National Private Truck Council in consultation with the U.S. Department of Transportation Human Factors Coordinating Committee should cooperatively develop and disseminate a training and education module that includes information about the need for an adequate amount of quality sleep, strategies for avoiding sleep loss such as strategic napping, consideration of the behavioral and physiological consequences of sleepiness, and an awareness that sleep can occur suddenly and without warning to all drivers regardless of their age or experience. Because of the strides that have been made in this area in the other transportation modes, particularly in aviation by NASA Ames, the Board urges the FHWA to consult the other modal administrations before developing this training and education module.

Another measure that was relatively highly correlated with fatigue was split sleep patterns. Split sleep patterns also ranked fifth in importance in discriminating between long-haul and short-haul operations. The HOS regulations contain an exemption that allows drivers using Department of Transportation-approved sleeper berth equipment to accumulate the required 8 consecutive hours off duty resting in a sleeper berth in two separate periods totaling 8 hours (neither period to be less than 2 hours).

The findings of this study show that truckdrivers with split sleep patterns were obtaining about 8 hours of sleep in a 24-hour time period; however, they obtained it in segments, on average of 4 hours at a time. Research, not available at the time the regulations were drafted by the Interstate Commerce Commission, has shown that sleep accumulated in short time blocks is less refreshing than sleep accumulated in one long time period.[19] Other research indicates that "...the more sleep is disturbed or reduced, for whatever reason, the more likely an individual will inadvertently slip into sleep."[20] A review of police accident reports has also demonstrated that decrements in performance occur earlier for drivers using sleeper berths (or drivers

---

[19] Dinges, D.F. 1989. The nature of sleepiness: causes, contexts, and consequences. In: Stunkard, A.J.; Baum, A. Perspectives in behavioral medicine: eating, sleeping, and sex. Hillsdale, NJ: Lawrence Erblaum Associates: 147-179. Chapter 9 (p. 147).

[20] (a) Mitler and others (1988, p. 107). (b) Rosekind, M.R.; Gander, P.H.; Connell, L.J.; Co, E.L. 1994. Crew factors in flight operations X: alertness management in flight operations. NASA/FAA Technical Memorandum DOT/FAA/RD-93/18.

with split sleep patterns) than for other drivers. The same research determined that split-shift, sleeper berth use (that is, driving without an 8-hour consecutive rest period) increased the risk of fatality more than two-fold. Sleep duration has been found to be as important to the recovery of performance abilities as is the quality of sleep experience.[21] Of the drivers for whom information on duty hours was available, 19 of 26 drivers with split sleep patterns (73 percent) had slept in a sleeper berth.

In drafting its original regulations, the Interstate Commerce Commission (ICC) noted the lack of scientific evidence about the nature of fatigue. The ICC was clearly frustrated at being unable to base its regulations on an empirical understanding of driver fatigue. Given what is now known about the inferior nature of split sleep patterns, it is unclear that the ICC would have permitted sleeper berth drivers to divide their required 8-hour off-duty period into two segments. Although the Safety Board encourages the use of sleeper berths for strategic napping and recognizes that sleeper berths may allow for continuous sleep, truckdrivers should not be encouraged or permitted to split their sleep. The current hours-of-service regulations do not permit drivers who sleep at a residence or in a motel to split their sleep periods. This exemption applies only to drivers who use sleeper berths. The Safety Board understands that in 1937, when these regulations were written, economic considerations required that freight move continuously—to keep produce and dairy products from spoiling, for example. However, the advent of refrigerated trucks eliminated concerns about food spoilage. The Board is also aware that the trucking industry wanted the flexibility provided by having drivers rest in their sleeper berths while waiting for other tasks to be completed (such as loading of tanks with crude oil). This would enable drivers to begin driving as soon as the tasks were completed and to drive for at least the time that they spent resting in their berths.

Although the Board is aware of the importance of just-in-time deliveries to the economic well-being of the manufacturing industry, the Board does not believe that this flexibility should be permitted at the expense of safety. The Safety Board is not aware of any physiological or laboratory research regarding the effect of split sleep patterns on performance; however, the Board's analysis has shown that the length of the most recent sleep period is the most important factor in determining fatigue and that the continuous nature of that sleep also is very important. Consequently, the Safety Board is asking the Federal Highway Administration to complete rulemaking within 2 years to eliminate 49 CFR 395.1 paragraph (h), which allows drivers with sleeper berth equipment to cumulate the 8 hours of off-duty time in two separate periods.

---

[21] Hertz, R.P. 1988. Tractor-trailer driver fatality: the role of nonconsecutive rest in a sleeper berth. Accident Analysis and Prevention. 20(6): 431-439.

Therefore, as a result of this study, the National Transportation Safety Board recommends that the American Trucking Associations, Inc.:

> In cooperation with the Federal Highway Administration, the Professional Truck Driver Institute of America, the Commercial Vehicle Safety Alliance, and the National Private Truck Council, develop and disseminate, in consultation with the U.S. Department of Transportation Human Factors Coordinating Committee, a training and education module to inform truckdrivers of the hazards of driving while fatigued. It should include information about the need for an adequate amount of quality sleep, strategies for avoiding sleep loss such as strategic napping, consideration of the behavioral and physiological consequences of sleepiness, and an awareness that sleep can occur suddenly and without warning to all drivers regardless of their age or experience. (Class II, Priority Action) (H-95-5)

Also as a result of the study, the Safety Board issued safety recommendations to the Federal Highway Administration, the Professional Truck Driver Institute of America, the Commercial Vehicle Safety Alliance, the National Private Truck Council, the Independent Truck Owner Operators, the Owner-Operator Independent Driver's Association, the International Brotherhood of Teamsters, and the National Industrial Transportation League.

The National Transportation Safety Board is an independent Federal agency with the statutory responsibility "...to promote transportation safety by conducting independent accident investigations and by formulating safety improvement recommendations" (Public Law 93-633). The Safety Board is vitally interested in any actions taken as a result of its safety recommendations and would appreciate a response from you regarding action taken or contemplated with respect to the recommendation in this letter. Please refer to Safety Recommendation H-95-5 in your reply.

Chairman HALL and Members HAMMERSCHMIDT and FRANCIS concurred in this recommendation.

By: Jim Hall
Chairman

Log 578A

National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: February 7, 1995

In reply refer to: H-95-5

Mr. Edward E. Kynaston
President
Professional Truck Driver
Institute of America
8788 Elk Grove Boulevard, Suite 20
Elk Grove, California 95624

A Safety Board analysis of Fatal Accident Reporting System (FARS) data indicates that in 1993 there were 3,311 heavy trucks involved in 3,169 fatal accidents. In these accidents, 3,783 persons died (432 were occupants of the heavy trucks).[1] Research has suggested that truckdriver fatigue may be a contributing factor in as many as 30 to 40 percent of all heavy truck accidents.[2] In 1990, the Safety Board completed a study of 182 heavy truck accidents that were fatal to the truckdriver.[3] These 182 accidents were a census of the heavy truck accidents that were fatal to the driver in the eight States that participated. The primary purpose in investigating fatal-to-the-driver heavy truck accidents was to assess the role of alcohol and other drugs in these accidents. The study found, however, that the most frequently cited probable cause was fatigue. The Board believes that the 31 percent incidence of fatigue in fatal-to-the-truckdriver accidents found in the 1990 study represents a valid estimate of the portion of fatal-to-the-driver heavy truck accidents that are fatigue-related. Little data are available to estimate the incidence of fatigue in the less severe heavy truck accidents.

[1] For this analysis, the Board defined a heavy truck as one >26,000 pounds gross vehicle weight.

[2] (a) Knipling, Ronald R.; Wang, Jing-Shiarn. 1994. Crashes and fatalities related to driver drowsiness/fatigue. Research Note. Washington, DC: U.S. Department of Transportation, National Highway Traffic Safety Administration. November. (b) Ryder, Andrew, ed. 1990. A system in need of overhaul. In: Driver fatigue, Part 1. Heavy duty trucking. September: 69-73.

[3] National Transportation Safety Board. 1990. Fatigue, alcohol, other drugs, and medical factors in fatal-to-the-driver heavy truck crashes. Safety Study NTSB/SS-90/01. Washington, DC.

Because of the significant number of heavy truck-related fatalities and the role of fatigue in such accidents, the Board initiated a study of single-vehicle heavy truck accidents to examine the role of specific factors that affect driver fatigue, such as drivers' patterns of duty and sleep, in heavy truck accidents and to determine potential remedial actions. Most research of the factors associated with fatigue involve laboratory studies that examine the effect of sleep deprivation on the operator's performance of specific tasks, such as controlled driving in which various physiological measures are documented, or involve retrospective reviews of accident records, such as police records, which contain limited data and are not designed to assess the role of human performance factors in fatigue-related accidents. The Safety Board is in a unique position to study the role of human performance factors that contribute to fatigue-related accidents. Accident investigation is the primary function of the Board, and it has been examining the role of human performance factors (and fatigue in particular) in accidents in all transportation modes for many years. Therefore, this study[4] of actual accidents provides a unique opportunity to examine the factors that contribute to fatigue-related accidents.

Because the purpose of the Board's study was to examine the factors that affect driver fatigue and not the statistical incidence of fatigue, the Board specifically selected truck accidents that were likely to include fatigue-related accidents; that is, single-vehicle accidents that tend to occur at night. The Board desired to obtain approximately an equal number of fatigue-related and nonfatigue-related accidents through its notification process to examine the differences between the two groups. From September 1992 through June 1993, the Board was notified by authorities in the States of Alabama, California, Georgia, New Jersey, North Carolina, and Texas[5] of single-vehicle accidents. During this period, the Board accepted sequentially for investigation, with no prejudgment of fatigue involvement, those accidents that occurred within a reasonable driving distance from the Board's regional offices and in which the vehicle was available for examination and the driver was available to be interviewed.

The Board was specifically interested in obtaining accurate information regarding the truckdrivers' duty and sleep patterns for the 96 hours preceding the accident; therefore, the Board limited the accidents to those in which the driver survived and was available to be interviewed by the Board's investigators to reconstruct the previous 96 hours. The Board did not rely solely on the drivers' official log books because of concern that inaccurate or incomplete information might have been recorded and because total sleep time is not required to be reported.

---

[4] National Transportation Safety Board. 1995. Factors that affect fatigue in heavy truck accidents. Volume 1: analysis. Safety Study NTSB/SS-95/01. Washington, DC.

[5] According to FARS data, in 1992 about 27 percent of fatal accidents involving large trucks in the United States occurred in these six States.

The Safety Board investigated 113 single-vehicle heavy truck accidents in which the driver survived. However, because the 96-hour duty/sleep history that was required for the study was not available for 6 drivers, the 6 accidents in which these drivers were involved were not included in the study. The study, therefore, analyzes data from 107 single-vehicle heavy truck accidents.[6]

The Board examined several measures of duty time, driving time, awake time, and sleeping time for the drivers. These measures included (1) the number of hours awake, driving, on duty, and sleeping in the 24-, 48-, 72-, and 96-hour periods before the accident, (2) the number of hours driving since the driver had last slept, (3) the number of hours driving in the period most recent to the accident, (4) the number of hours on duty prior to the accident (including nondriving activities such as loading and unloading cargo, truck inspections, paperwork, calling dispatchers, and waiting at terminals), (5) the number of hours since the driver had last slept, and (6) the number of hours slept in the sleep period most recent to the accident.[7] These measures were taken from the 96-hour logs that were reconstructed from the Safety Board investigators' interviews with the drivers.

The Board also examined the drivers' duty/sleep patterns for the 96-hour period before the accident. The Board established five measures of the drivers' duty/sleep patterns. The five dichotomous (yes/no) measures included irregular duty, irregular sleep, both irregular duty and sleep, regular duty and sleep, and regular sleep with nonclassifiable duty.[8] These five measures are mutually exclusive. The Board also identified three other schedule-related measures that could occur for a driver with either regular or irregular duty/sleep patterns. They include inverted duty/sleep, split sleep patterns, and exceeded hours-of-service limits (exceeded HOS limits).

A total of 21 measures were used to characterize drivers' patterns and amounts of duty and sleep in the 96 hours prior to the accident.[9] Of the 107 drivers, the complete set of duty/sleep measures could not be computed for 20 drivers; hence, data from only 87 drivers were available for analysis (51 were involved in fatigue-related

---

[6] Volume 2 of this study (NTSB/SS-95/02) contains the briefs of the 107 accidents investigated by the Safety Board.

[7] For purposes of discussion in this study, these measures have been termed "duty/sleep time measures."

[8] If a driver did not have at least three consecutive start times, his duty hours were considered "nonclassifiable."

[9] The majority of the single-vehicle accidents in the Safety Board's sample occurred between 2 and 8 a.m. (53 percent), and an even higher percentage of the accidents that were determined to be fatigue-related occurred during these same hours (75 percent). Time of day was not included as one of the 21 measures because of the inherent bias in the sample of cases; that is, single-vehicle accidents are likely to occur at night when traffic is light or sparse.

accidents, 36 were not). As would be expected, the driving and duty times of the 20 excluded drivers were less than those of the 87 drivers who had not had days off. Eleven of the 20 excluded drivers were involved in fatigue-related accidents, and the remaining 9 drivers were involved in nonfatigue-related accidents.

A multiple discriminant analysis[10] was performed to simultaneously evaluate the relationship of a set of 18 predictor measures[11] to the groupings of accidents established by investigators' determination of probable cause (fatigue-related and nonfatigue-related accidents). In the present case, discriminant analysis provides a means of simultaneously examining the capacity of the interrelated sleep, duty, and scheduling measures to classify an accident as either fatigue-related or nonfatigue-related. The combination of measures resulting from the application of the discriminant analysis to the Board's 87 accidents was able to correctly classify 94.4 percent of the nonfatigue-related accidents and 80.4 percent of the fatigue-related accidents—a very high rate of successful classification.[12]

The results of the discriminant analysis indicate that the most critical measures in predicting fatigue-related accidents in the Safety Board's sample are the duration of the most recent sleep period, the amount of sleep in the past 24 hours, and split sleep patterns. It is not surprising that sleep factors rated high in this analysis given the results of extensive scientific research in this area. However, the Board believes that it is noteworthy in this unique sample of actual accidents that factors that affect the ability to obtain adequate sleep, such as irregular duty/sleep and inverted schedules (which are often assumed to be closely associated with fatigue), ranked well below the factors that affect the quantity and quality of sleep.[13]

The truckdrivers in fatigue-related accidents in this sample obtained on average 5.5 hours of sleep in the last sleep period prior to the accident. This is 1.4 hours less than the 6.9 hours they reported needing to feel rested and 2.5 hours less than that obtained by drivers in nonfatigue-related accidents (8.0 hours of sleep in the last sleep period). The findings further indicate that the truckdrivers involved

---

[10] A description of discriminant analysis can be found in the following publication: Tabachnick, B G.; Fidell, L S 1989. Using multivariate statistics. 2nd ed. New York: Harper & Row. 746 p.

[11] Because hours awake and hours asleep in the last 24 or 48 hours were complements of one another, only the time asleep measures were included in the analysis. Similarly, the scheduling measure of regular sleep/duty was not included because it is simply the complement of irregular duty/sleep. Thus, the set of predictors was reduced to 18 measures.

[12] Details of the discriminant analysis are contained in chapter 4 and appendix D of the study (NTSB/SS-95/01).

[13] Although the Safety Board examined single-vehicle accidents, there is no reason to believe that the factors that were associated with fatigue-related single-vehicle accidents would be any different in other kinds of accidents. The Board believes, therefore, that the results of this study can be generalized to the trucking population as a whole.

in fatigue-related accidents obtained about 2.4 hours less sleep in the 24-hour period before the accident than the drivers not involved in fatigue-related accidents (6.9 hours compared to 9.3 hours).

The data indicate that the mean time awake, but not on duty, for the drivers in the fatigue-related accidents was about 5.5 hours. This suggests that these drivers could have readily attained more than the mean of 5.5 hours of sleep during the last sleep period prior to the accident. However, the timing of the awake period may not have fit with the driving schedule to permit 8 hours continuous sleep in the last sleep period. Further, the drivers have a need to attend to family duties and other responsibilities. The fact that drivers in nonfatigue-related accidents also were awake about 5.5 hours while off duty (but still attained 8 hours sleep in the most recent sleep period prior to the accident) suggests that 5.5 hours is not an unreasonable period of time to be allocated to such needs. It appears, therefore, that if the driving or on-duty time is pushed to the maximum hours allowed, drivers will reduce the amount of time for sleep rather than the time needed to accomplish other duties and responsibilities.

Research indicates that the amount of sleep needed varies on an individual basis: "...for some it is 5 to 6 hours a night, for others it is...7 or 8 hours, and for still others it is 9 to 10 hours."[14] The Safety Board recognizes that all truckdrivers do not need 8 hours of sleep. However, responsible public policy dictates that drivers of heavy trucks be able to obtain adequate sleep between work assignments. Implementation of this policy, in the form of Federal regulations or industry procedures and practices, cannot generally address drivers on an individual basis. Thus, implementation of this policy must address the norm, which research has determined to be 8 hours—a fact noted by the ICC in 1937.[15] The results of this study support the need by the "average" driver for 8 continuous hours of sleep.

The Safety Board recognizes that regulations cannot assure that adequate sleep will be obtained. Nevertheless, the regulations can and must provide the opportunity to obtain an adequate amount of rest. However, the 8-hour off-duty requirement in the current regulations does not do so because it does not provide time for travel, eating, personal hygiene, and recreation. Further, depending on various factors, including the time of day, a driver may not be able to fall asleep immediately at the beginning of the 8-hour off-duty period. Because the results of this accident sample are unlikely to be substantially enhanced by any further research, these results provide a solid basis for sound policy decisions. The Board also recognizes that the inadequate sleep obtained may not be directly related to the

---

[14] Dinges, D F. 1984. The nature and timing of sleep. Transactions & Studies of the College of Physicians of Philadelphia. Ser 5:6(3): 177-206 (p. 198).

[15] (a) Carskadon, M.S.; Dement, W.C. (1994). (b) Carskadon, Mary A., ed. 1993. Encyclopedia of sleep and dreaming. New York: Macmillan Publishing Company.

8-hour off-duty requirement in the HOS regulations. However, in the Safety Board's view, a minimum standard that does not provide for at least 8 hours of sleep is not responsible public policy and could be construed as condoning less than 8 hours of sleep as adequate, when the time needed for eating, hygiene, and recreation is considered. Therefore, the Board is asking the FHWA to complete rulemaking within 2 years to revise 49 CFR 395.1 to require sufficient rest provisions to enable drivers to obtain at least 8 continuous hours of sleep.

Given the results of the latest research and studies on fatigue and sleep issues, the Board believes that steps can be taken now to provide truckdrivers with the opportunity to obtain 8 hours of sleep and that the trucking industry can take a lead role in this effort. Therefore, the Safety Board believes that the trucking industry should incorporate into its scheduling practices and procedures the results of the latest research on fatigue and sleep issues, particularly that an 8-hour sleep need is the norm. The Safety Board believes that current scheduling practices can accommodate a change in the rest period without resulting in undue economic hardships. The Safety Board believes that the majority of trucking companies currently comply with the hours-of-service regulations and that an increase in the amount of off-duty time would not change the way they schedule their deliveries or require changes in the locations of terminals. The data in this sample show that the truckdrivers involved in nonfatigue-related accidents were typically on duty 9 hours a day. These drivers had sufficient time to obtain adequate sleep and, in fact, did obtain 8 hours of continuous sleep in their last sleep period.

The Safety Board recognizes that providing the opportunity to obtain adequate sleep will not assure that drivers actually obtain that sleep. The ICC recognized this in 1937, stating:

> We fully recognize that regulations of this kind cannot provide a complete answer to the problem of driver fatigue and its effect upon safety of operation. We have no control over the manner in which a driver may spend his time off duty, although some of his spare-time activities may tire him quite as much as any work would do. We can only emphasize, by this comment, the responsibility which is the driver's own to assure himself of adequate rest and sleep, in the time available for this purpose, to ensure the safety of his driving, and likewise the employer's responsibility to see that his drivers report for work in fit condition.

Although drivers have a responsibility to obtain adequate rest and sleep, they must first recognize that they need sleep. Many of the truckdrivers in the Safety Board's accident sample who were involved in fatigue-related accidents did not recognize that they were in need of sleep and believed that they were rested when they were not. Drivers in both fatigue-related and nonfatigue-related accidents rated themselves as being okay to fully alert before the accident. Further, about 80 percent

of the drivers involved in fatigue-related accidents rated the quality of their last sleep before the accident as good or excellent. Drivers in fatigue-related accidents received about 1.4 hours less sleep than they reported needing to feel rested. Research has indicated that people "...have a limited ability to predict the onset of sleep...[and that]...subjects certainly do fall asleep at times when they think sleep is highly unlikely."[16]

"Inadequate sleep, even as little as 1 or 2 hours less than usual sleep, can greatly exaggerate the tendency for error during the time zones of vulnerability (1 to about 8 a.m. and 2 to roughly 6 p.m.)."[17] The majority of the accidents in this sample occurred between 2 and 8 a.m. (53 percent), and an even higher percentage of the accidents that were found to be fatigue-related occurred during these same hours (75 percent). Driving at night, as many truckdrivers must do, is complicated by the effects of circadian rhythms. Thus, a sleep deprived person driving at night is in the highest risk situation—a risk that many drivers may not be aware of or recognize.

Modifying the regulations to increase the off-duty period will not, by itself, eliminate the problem of truckdriver fatigue. Educating transportation employees about the effects of fatigue, in the Safety Board's view, is a vitally important component of overall efforts to combat fatigue in transportation. The Board recognizes that there is a considerable amount of research underway that could eventually be used to develop or modify programs designed to educate operators of heavy trucks and other industry personnel, in particular management, about the importance of sleep loss and other factors in fatigue-related accidents. However, the Board believes that this study and other research have provided important information that could be provided now to truckdrivers and management about factors leading to fatigue and possible strategies to combat fatigue. In addition to studies discussed above, the NASA Ames Fatigue Countermeasures Program stands out as demonstrating some especially effective countermeasures. This program, which has been underway since 1980, has addressed strategic napping as a preventive strategy and an operational countermeasure to combat sleep loss, circadian disruption, and fatigue that occur as a result of multiple time zone changes, and extended, irregular duty schedules in flight operations.[18] The researchers found that there is scientific evidence showing that as a preventive strategy, napping before

---

[16] Itoi, A.; Cilveti, R.; Voth, M.; and others. 1993. Can drivers avoid falling asleep at the wheel? Relationship between awareness of sleepiness and ability to predict sleep onset. Washington, DC: AAA Foundation for Traffic Safety (p. 25). 33 p.

[17] Mitler, M.; Carskadon, M.A.; Czeisler, C.A.; and others. 1988. Catastrophes, sleep and public policy: consensus report. Sleep. 11(1): 100-109.

[18] Rosekind, Mark R.; Graeber, R. Curtis; Dinges, David F.; and others. 1993. Crew factors in flight operations IX: Effects of planned cockpit rest on crew performance and alertness in long-haul flight operations. NASA Technical Memorandum 108839. DOT/FAA/92/24. Washington, DC.

fatigue develops is quite effective in an operational setting. A single nap of about 45 minutes in duration prior to a night without sleep can prevent significant loss of performance capability and fatigue throughout the night. The Safety Board agrees that the use of naps as a means to prevent fatigue prior to its onset is a worthwhile countermeasure. The Board cautions, however, that these naps should be a supplement to, not a replacement for, one continuous 8-hour sleep period.

Therefore, the Safety Board believes that the Federal Highway Administration, the Professional Truck Driver Institute of America, the American Trucking Associations, Inc., and the Commercial Vehicle Safety Alliance, and the National Private Truck Council in consultation with the U.S. Department of Transportation Human Factors Coordinating Committee should cooperatively develop and disseminate a training and education module that includes information about the need for an adequate amount of quality sleep, strategies for avoiding sleep loss such as strategic napping, consideration of the behavioral and physiological consequences of sleepiness, and an awareness that sleep can occur suddenly and without warning to all drivers regardless of their age or experience. Because of the strides that have been made in this area in the other transportation modes, particularly in aviation by NASA Ames, the Board urges the FHWA to consult the other modal administrations before developing this training and education module.

Another measure that was relatively highly correlated with fatigue was split sleep patterns. Split sleep patterns also ranked fifth in importance in discriminating between long-haul and short-haul operations. The HOS regulations contain an exemption that allows drivers using Department of Transportation-approved sleeper berth equipment to accumulate the required 8 consecutive hours off duty resting in a sleeper berth in two separate periods totaling 8 hours (neither period to be less than 2 hours).

The findings of this study show that truckdrivers with split sleep patterns were obtaining about 8 hours of sleep in a 24-hour time period; however, they obtained it in segments, on average of 4 hours at a time. Research, not available at the time the regulations were drafted by the Interstate Commerce Commission, has shown that sleep accumulated in short time blocks is less refreshing than sleep accumulated in one long time period.[19] Other research indicates that "...the more sleep is disturbed or reduced, for whatever reason, the more likely an individual will inadvertently slip into sleep."[20] A review of police accident reports has also demonstrated that decrements in performance occur earlier for drivers using sleeper berths (or drivers

---

[19] Dinges, D.F. 1989. The nature of sleepiness: causes, contexts, and consequences. In: Stunkard, A.J.; Baum, A. Perspectives in behavioral medicine: eating, sleeping, and sex. Hillsdale, NJ: Lawrence Erblaum Associates: 147-179. Chapter 9 (p. 147).

[20] (a) Mitler and others (1988, p. 107). (b) Rosekind, M.R.; Gander, P.H.; Connell, L.J.; Co, E.L. 1994. Crew factors in flight operations X: alertness management in flight operations. NASA/FAA Technical Memorandum DOT/FAA/RD-93/18.

with split sleep patterns) than for other drivers. The same research determined that split-shift, sleeper berth use (that is, driving without an 8-hour consecutive rest period) increased the risk of fatality more than two-fold. Sleep duration has been found to be as important to the recovery of performance abilities as is the quality of sleep experience.[21] Of the drivers for whom information on duty hours was available, 19 of 26 drivers with split sleep patterns (73 percent) had slept in a sleeper berth.

In drafting its original regulations, the Interstate Commerce Commission (ICC) noted the lack of scientific evidence about the nature of fatigue. The ICC was clearly frustrated at being unable to base its regulations on an empirical understanding of driver fatigue. Given what is now known about the inferior nature of split sleep patterns, it is unclear that the ICC would have permitted sleeper berth drivers to divide their required 8-hour off-duty period into two segments. Although the Safety Board encourages the use of sleeper berths for strategic napping and recognizes that sleeper berths may allow for continuous sleep, truckdrivers should not be encouraged or permitted to split their sleep. The current hours-of-service regulations do not permit drivers who sleep at a residence or in a motel to split their sleep periods. This exemption applies only to drivers who use sleeper berths. The Safety Board understands that in 1937, when these regulations were written, economic considerations required that freight move continuously—to keep produce and dairy products from spoiling, for example. However, the advent of refrigerated trucks eliminated concerns about food spoilage. The Board is also aware that the trucking industry wanted the flexibility provided by having drivers rest in their sleeper berths while waiting for other tasks to be completed (such as loading of tanks with crude oil). This would enable drivers to begin driving as soon as the tasks were completed and to drive for at least the time that they spent resting in their berths.

Although the Board is aware of the importance of just-in-time deliveries to the economic well-being of the manufacturing industry, the Board does not believe that this flexibility should be permitted at the expense of safety. The Safety Board is not aware of any physiological or laboratory research regarding the effect of split sleep patterns on performance; however, the Board's analysis has shown that the length of the most recent sleep period is the most important factor in determining fatigue and that the continuous nature of that sleep also is very important. Consequently, the Safety Board is asking the Federal Highway Administration to complete rulemaking within 2 years to eliminate 49 CFR 395.1 paragraph (h), which allows drivers with sleeper berth equipment to cumulate the 8 hours of off-duty time in two separate periods.

---

[21] Hertz, R.P. 1988. Tractor-trailer driver fatality: the role of nonconsecutive rest in a sleeper berth. Accident Analysis and Prevention. 20(6): 431-439.

Therefore, as a result of this study, the National Transportation Safety Board recommends that the Professional Truck Driver Institute of America:

> In cooperation with the Federal Highway Administration, the Commercial Vehicle Safety Alliance, the American Trucking Associations Inc., and the National Private Truck Council, develop and disseminate, in consultation with the U.S. Department of Transportation Human Factors Coordinating Committee, a training and education module to inform truckdrivers of the hazards of driving while fatigued. It should include information about the need for an adequate amount of quality sleep, strategies for avoiding sleep loss such as strategic napping, consideration of the behavioral and physiological consequences of sleepiness, and an awareness that sleep can occur suddenly and without warning to all drivers regardless of their age or experience. (Class II, Priority Action) (H-95-5)

Also as a result of the study, the Safety Board issued safety recommendations to the Federal Highway Administration, the Commercial Vehicle Safety Alliance, the American Trucking Associations Inc., the National Private Truck Council, the Independent Truck Owner Operators, the Owner-Operator Independent Driver's Association, the International Brotherhood of Teamsters, and the National Industrial Transportation League.

The National Transportation Safety Board is an independent Federal agency with the statutory responsibility "...to promote transportation safety by conducting independent accident investigations and by formulating safety improvement recommendations" (Public Law 93-633). The Safety Board is vitally interested in any actions taken as a result of its safety recommendations and would appreciate a response from you regarding action taken or contemplated with respect to the recommendation in this letter. Please refer to Safety Recommendation H-95-5 in your reply.

Chairman HALL and Members HAMMERSCHMIDT and FRANCIS concurred in this recommendation.

By: Jim Hall
Chairman

Log 578A

National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: February 7, 1995

In reply refer to: H-95-5

Mr. Russ Fiste
Executive Director
Commercial Vehicle Safety Alliance
5430 Grosvenor Lane, Suite 130
Bethesda, Maryland 20814

A Safety Board analysis of Fatal Accident Reporting System (FARS) data indicates that in 1993 there were 3,311 heavy trucks involved in 3,169 fatal accidents. In these accidents, 3,783 persons died (432 were occupants of the heavy trucks).[1] Research has suggested that truckdriver fatigue may be a contributing factor in as many as 30 to 40 percent of all heavy truck accidents.[2] In 1990, the Safety Board completed a study of 182 heavy truck accidents that were fatal to the truckdriver.[3] These 182 accidents were a census of the heavy truck accidents that were fatal to the driver in the eight States that participated. The primary purpose in investigating fatal-to-the-driver heavy truck accidents was to assess the role of alcohol and other drugs in these accidents. The study found, however, that the most frequently cited probable cause was fatigue. The Board believes that the 31 percent incidence of fatigue in fatal-to-the-truckdriver accidents found in the 1990 study represents a valid estimate of the portion of fatal-to-the-driver heavy truck accidents that are fatigue-related. Little data are available to estimate the incidence of fatigue in the less severe heavy truck accidents.

[1] For this analysis, the Board defined a heavy truck as one >26,000 pounds gross vehicle weight.

[2] (a) Knipling, Ronald R.; Wang, Jing-Shiarn. 1994. Crashes and fatalities related to driver drowsiness/fatigue. Research Note. Washington, DC: U.S. Department of Transportation, National Highway Traffic Safety Administration. November. (b) Ryder, Andrew, ed. 1990. A system in need of overhaul. In: Driver fatigue, Part 1. Heavy duty trucking. September: 69-73.

[3] National Transportation Safety Board. 1990. Fatigue, alcohol, other drugs, and medical factors in fatal-to-the-driver heavy truck crashes. Safety Study NTSB/SS-90/01. Washington, DC.

Because of the significant number of heavy truck-related fatalities and the role of fatigue in such accidents, the Board initiated a study of single-vehicle heavy truck accidents to examine the role of specific factors that affect driver fatigue, such as drivers' patterns of duty and sleep, in heavy truck accidents and to determine potential remedial actions. Most research of the factors associated with fatigue involve laboratory studies that examine the effect of sleep deprivation on the operator's performance of specific tasks, such as controlled driving in which various physiological measures are documented, or involve retrospective reviews of accident records, such as police records, which contain limited data and are not designed to assess the role of human performance factors in fatigue-related accidents. The Safety Board is in a unique position to study the role of human performance factors that contribute to fatigue-related accidents. Accident investigation is the primary function of the Board, and it has been examining the role of human performance factors (and fatigue in particular) in accidents in all transportation modes for many years. Therefore, this study[4] of actual accidents provides a unique opportunity to examine the factors that contribute to fatigue-related accidents.

Because the purpose of the Board's study was to examine the factors that affect driver fatigue and not the statistical incidence of fatigue, the Board specifically selected truck accidents that were likely to include fatigue-related accidents; that is, single-vehicle accidents that tend to occur at night. The Board desired to obtain approximately an equal number of fatigue-related and nonfatigue-related accidents through its notification process to examine the differences between the two groups. From September 1992 through June 1993, the Board was notified by authorities in the States of Alabama, California, Georgia, New Jersey, North Carolina, and Texas[5] of single-vehicle accidents. During this period, the Board accepted sequentially for investigation, with no prejudgment of fatigue involvement, those accidents that occurred within a reasonable driving distance from the Board's regional offices and in which the vehicle was available for examination and the driver was available to be interviewed.

The Board was specifically interested in obtaining accurate information regarding the truckdrivers' duty and sleep patterns for the 96 hours preceding the accident; therefore, the Board limited the accidents to those in which the driver survived and was available to be interviewed by the Board's investigators to reconstruct the previous 96 hours. The Board did not rely solely on the drivers' official log books because of concern that inaccurate or incomplete information might have been recorded and because total sleep time is not required to be reported.

---

[4] National Transportation Safety Board. 1995. Factors that affect fatigue in heavy truck accidents. Volume 1: analysis. Safety Study NTSB/SS-95/01. Washington, DC.

[5] According to FARS data, in 1992 about 27 percent of fatal accidents involving large trucks in the United States occurred in these six States.

The Safety Board investigated 113 single-vehicle heavy truck accidents in which the driver survived. However, because the 96-hour duty/sleep history that was required for the study was not available for 6 drivers, the 6 accidents in which these drivers were involved were not included in the study. The study, therefore, analyzes data from 107 single-vehicle heavy truck accidents.[6]

The Board examined several measures of duty time, driving time, awake time, and sleeping time for the drivers. These measures included (1) the number of hours awake, driving, on duty, and sleeping in the 24-, 48-, 72-, and 96-hour periods before the accident, (2) the number of hours driving since the driver had last slept, (3) the number of hours driving in the period most recent to the accident, (4) the number of hours on duty prior to the accident (including nondriving activities such as loading and unloading cargo, truck inspections, paperwork, calling dispatchers, and waiting at terminals), (5) the number of hours since the driver had last slept, and (6) the number of hours slept in the sleep period most recent to the accident.[7] These measures were taken from the 96-hour logs that were reconstructed from the Safety Board investigators' interviews with the drivers.

The Board also examined the drivers' duty/sleep patterns for the 96-hour period before the accident. The Board established five measures of the drivers' duty/sleep patterns. The five dichotomous (yes/no) measures included irregular duty, irregular sleep, both irregular duty and sleep, regular duty and sleep, and regular sleep with nonclassifiable duty.[8] These five measures are mutually exclusive. The Board also identified three other schedule-related measures that could occur for a driver with either regular or irregular duty/sleep patterns. They include inverted duty/sleep, split sleep patterns, and exceeded hours-of-service limits (exceeded HOS limits).

A total of 21 measures were used to characterize drivers' patterns and amounts of duty and sleep in the 96 hours prior to the accident.[9] Of the 107 drivers, the complete set of duty/sleep measures could not be computed for 20 drivers; hence, data from only 87 drivers were available for analysis (51 were involved in fatigue-related

---

[6] Volume 2 of this study (NTSB/SS-95/02) contains the briefs of the 107 accidents investigated by the Safety Board

[7] For purposes of discussion in this study, these measures have been termed "duty/sleep time measures."

[8] If a driver did not have at least three consecutive start times, his duty hours were considered "nonclassifiable."

[9] The majority of the single-vehicle accidents in the Safety Board's sample occurred between 2 and 8 a.m. (53 percent), and an even higher percentage of the accidents that were determined to be fatigue-related occurred during these same hours (75 percent). Time of day was not included as one of the 21 measures because of the inherent bias in the sample of cases; that is, single-vehicle accidents are likely to occur at night when traffic is light or sparse.

accidents, 36 were not). As would be expected, the driving and duty times of the 20 excluded drivers were less than those of the 87 drivers who had not had days off. Eleven of the 20 excluded drivers were involved in fatigue-related accidents, and the remaining 9 drivers were involved in nonfatigue-related accidents.

A multiple discriminant analysis[10] was performed to simultaneously evaluate the relationship of a set of 18 predictor measures[11] to the groupings of accidents established by investigators' determination of probable cause (fatigue-related and nonfatigue-related accidents). In the present case, discriminant analysis provides a means of simultaneously examining the capacity of the interrelated sleep, duty, and scheduling measures to classify an accident as either fatigue-related or nonfatigue-related. The combination of measures resulting from the application of the discriminant analysis to the Board's 87 accidents was able to correctly classify 94.4 percent of the nonfatigue-related accidents and 80.4 percent of the fatigue-related accidents—a very high rate of successful classification.[12]

The results of the discriminant analysis indicate that the most critical measures in predicting fatigue-related accidents in the Safety Board's sample are the duration of the most recent sleep period, the amount of sleep in the past 24 hours, and split sleep patterns. It is not surprising that sleep factors rated high in this analysis given the results of extensive scientific research in this area. However, the Board believes that it is noteworthy in this unique sample of actual accidents that factors that affect the ability to obtain adequate sleep, such as irregular duty/sleep and inverted schedules (which are often assumed to be closely associated with fatigue), ranked well below the factors that affect the quantity and quality of sleep.[13]

The truckdrivers in fatigue-related accidents in this sample obtained on average 5.5 hours of sleep in the last sleep period prior to the accident. This is 1.4 hours less than the 6.9 hours they reported needing to feel rested and 2.5 hours less than that obtained by drivers in nonfatigue-related accidents (8.0 hours of sleep in the last sleep period). The findings further indicate that the truckdrivers involved

---

[10] A description of discriminant analysis can be found in the following publication: Tabachnick, B.G.; Fidell, L.S. 1989. Using multivariate statistics. 2nd ed. New York: Harper & Row. 746 p.

[11] Because hours awake and hours asleep in the last 24 or 48 hours were complements of one another, only the time asleep measures were included in the analysis. Similarly, the scheduling measure of regular sleep/duty was not included because it is simply the complement of irregular duty/sleep. Thus, the set of predictors was reduced to 18 measures.

[12] Details of the discriminant analysis are contained in chapter 4 and appendix D of the study (NTSB/SS-95/01).

[13] Although the Safety Board examined single-vehicle accidents, there is no reason to believe that the factors that were associated with fatigue-related single-vehicle accidents would be any different in other kinds of accidents. The Board believes, therefore, that the results of this study can be generalized to the trucking population as a whole.

in fatigue-related accidents obtained about 2.4 hours less sleep in the 24-hour period before the accident than the drivers not involved in fatigue-related accidents (6.9 hours compared to 9.3 hours).

The data indicate that the mean time awake, but not on duty, for the drivers in the fatigue-related accidents was about 5.5 hours. This suggests that these drivers could have readily attained more than the mean of 5.5 hours of sleep during the last sleep period prior to the accident. However, the timing of the awake period may not have fit with the driving schedule to permit 8 hours continuous sleep in the last sleep period. Further, the drivers have a need to attend to family duties and other responsibilities. The fact that drivers in nonfatigue-related accidents also were awake about 5.5 hours while off duty (but still attained 8 hours sleep in the most recent sleep period prior to the accident) suggests that 5.5 hours is not an unreasonable period of time to be allocated to such needs. It appears, therefore, that if the driving or on-duty time is pushed to the maximum hours allowed, drivers will reduce the amount of time for sleep rather than the time needed to accomplish other duties and responsibilities.

Research indicates that the amount of sleep needed varies on an individual basis: "...for some it is 5 to 6 hours a night, for others it is...7 or 8 hours, and for still others it is 9 to 10 hours."[14] The Safety Board recognizes that all truckdrivers do not need 8 hours of sleep. However, responsible public policy dictates that drivers of heavy trucks be able to obtain adequate sleep between work assignments. Implementation of this policy, in the form of Federal regulations or industry procedures and practices, cannot generally address drivers on an individual basis. Thus, implementation of this policy must address the norm, which research has determined to be 8 hours—a fact noted by the ICC in 1937.[15] The results of this study support the need by the "average" driver for 8 continuous hours of sleep.

The Safety Board recognizes that regulations cannot assure that adequate sleep will be obtained. Nevertheless, the regulations can and must provide the opportunity to obtain an adequate amount of rest. However, the 8-hour off-duty requirement in the current regulations does not do so because it does not provide time for travel, eating, personal hygiene, and recreation. Further, depending on various factors, including the time of day, a driver may not be able to fall asleep immediately at the beginning of the 8-hour off-duty period. Because the results of this accident sample are unlikely to be substantially enhanced by any further research, these results provide a solid basis for sound policy decisions. The Board also recognizes that the inadequate sleep obtained may not be directly related to the

---

[14] Dinges, D.F. 1984 The nature and timing of sleep Transactions & Studies of the College of Physicians of Philadelphia Ser 5:6(3): 177-206 (p 198).

[15] (a) Carskadon, M.S.; Dement, W C (1994). (b) Carskadon, Mary A., ed. 1993 Encyclopedia of sleep and dreaming New York: Macmillan Publishing Company

8-hour off-duty requirement in the HOS regulations. However, in the Safety Board's view, a minimum standard that does not provide for at least 8 hours of sleep is not responsible public policy and could be construed as condoning less than 8 hours of sleep as adequate, when the time needed for eating, hygiene, and recreation is considered. Therefore, the Board is asking the FHWA to complete rulemaking within 2 years to revise 49 CFR 395.1 to require sufficient rest provisions to enable drivers to obtain at least 8 continuous hours of sleep.

Given the results of the latest research and studies on fatigue and sleep issues, the Board believes that steps can be taken now to provide truckdrivers with the opportunity to obtain 8 hours of sleep and that the trucking industry can take a lead role in this effort. Therefore, the Safety Board believes that the trucking industry should incorporate into its scheduling practices and procedures the results of the latest research on fatigue and sleep issues, particularly that an 8-hour sleep need is the norm. The Safety Board believes that current scheduling practices can accommodate a change in the rest period without resulting in undue economic hardships. The Safety Board believes that the majority of trucking companies currently comply with the hours-of-service regulations and that an increase in the amount of off-duty time would not change the way they schedule their deliveries or require changes in the locations of terminals. The data in this sample show that the truckdrivers involved in nonfatigue-related accidents were typically on duty 9 hours a day. These drivers had sufficient time to obtain adequate sleep and, in fact, did obtain 8 hours of continuous sleep in their last sleep period.

The Safety Board recognizes that providing the opportunity to obtain adequate sleep will not assure that drivers actually obtain that sleep. The ICC recognized this in 1937, stating:

> We fully recognize that regulations of this kind cannot provide a complete answer to the problem of driver fatigue and its effect upon safety of operation. We have no control over the manner in which a driver may spend his time off duty, although some of his spare-time activities may tire him quite as much as any work would do. We can only emphasize, by this comment, the responsibility which is the driver's own to assure himself of adequate rest and sleep, in the time available for this purpose, to ensure the safety of his driving, and likewise the employer's responsibility to see that his drivers report for work in fit condition.

Although drivers have a responsibility to obtain adequate rest and sleep, they must first recognize that they need sleep. Many of the truckdrivers in the Safety Board's accident sample who were involved in fatigue-related accidents did not recognize that they were in need of sleep and believed that they were rested when they were not. Drivers in both fatigue-related and nonfatigue-related accidents rated themselves as being okay to fully alert before the accident. Further, about 80 percent

of the drivers involved in fatigue-related accidents rated the quality of their last sleep before the accident as good or excellent. Drivers in fatigue-related accidents received about 1.4 hours less sleep than they reported needing to feel rested. Research has indicated that people "...have a limited ability to predict the onset of sleep...[and that]...subjects certainly do fall asleep at times when they think sleep is highly unlikely."[16]

"Inadequate sleep, even as little as 1 or 2 hours less than usual sleep, can greatly exaggerate the tendency for error during the time zones of vulnerability (1 to about 8 a.m. and 2 to roughly 6 p.m.)."[17] The majority of the accidents in this sample occurred between 2 and 8 a.m. (53 percent), and an even higher percentage of the accidents that were found to be fatigue-related occurred during these same hours (75 percent). Driving at night, as many truckdrivers must do, is complicated by the effects of circadian rhythms. Thus, a sleep deprived person driving at night is in the highest risk situation—a risk that many drivers may not be aware of or recognize.

Modifying the regulations to increase the off-duty period will not, by itself, eliminate the problem of truckdriver fatigue. Educating transportation employees about the effects of fatigue, in the Safety Board's view, is a vitally important component of overall efforts to combat fatigue in transportation. The Board recognizes that there is a considerable amount of research underway that could eventually be used to develop or modify programs designed to educate operators of heavy trucks and other industry personnel, in particular management, about the importance of sleep loss and other factors in fatigue-related accidents. However, the Board believes that this study and other research have provided important information that could be provided now to truckdrivers and management about factors leading to fatigue and possible strategies to combat fatigue. In addition to studies discussed above, the NASA Ames Fatigue Countermeasures Program stands out as demonstrating some especially effective countermeasures. This program, which has been underway since 1980, has addressed strategic napping as a preventive strategy and an operational countermeasure to combat sleep loss, circadian disruption, and fatigue that occur as a result of multiple time zone changes, and extended, irregular duty schedules in flight operations.[18] The researchers found that there is scientific evidence showing that as a preventive strategy, napping before

---

[16] Itoi, A.; Cilveti, R.; Voth, M.; and others. 1993. Can drivers avoid falling asleep at the wheel? Relationship between awareness of sleepiness and ability to predict sleep onset. Washington, DC: AAA Foundation for Traffic Safety (p. 25). 33 p.

[17] Mitler, M.; Carskadon, M.A.; Czeisler, C.A.; and others. 1988. Catastrophes, sleep and public policy: consensus report. Sleep. 11(1): 100-109.

[18] Rosekind, Mark R.; Graeber, R. Curtis; Dinges, David F.; and others. 1993. Crew factors in flight operations. IX: Effects of planned cockpit rest on crew performance and alertness in long-haul flight operations. NASA Technical Memorandum 108839. DOT/FAA/92/24. Washington, DC.

fatigue develops is quite effective in an operational setting. A single nap of about 45 minutes in duration prior to a night without sleep can prevent significant loss of performance capability and fatigue throughout the night. The Safety Board agrees that the use of naps as a means to prevent fatigue prior to its onset is a worthwhile countermeasure. The Board cautions, however, that these naps should be a supplement to, not a replacement for, one continuous 8-hour sleep period.

Therefore, the Safety Board believes that the Federal Highway Administration, the Professional Truck Driver Institute of America, the American Trucking Associations, Inc., and the Commercial Vehicle Safety Alliance, and the National Private Truck Council in consultation with the U.S. Department of Transportation Human Factors Coordinating Committee should cooperatively develop and disseminate a training and education module that includes information about the need for an adequate amount of quality sleep, strategies for avoiding sleep loss such as strategic napping, consideration of the behavioral and physiological consequences of sleepiness, and an awareness that sleep can occur suddenly and without warning to all drivers regardless of their age or experience. Because of the strides that have been made in this area in the other transportation modes, particularly in aviation by NASA Ames, the Board urges the FHWA to consult the other modal administrations before developing this training and education module.

Another measure that was relatively highly correlated with fatigue was split sleep patterns. Split sleep patterns also ranked fifth in importance in discriminating between long-haul and short-haul operations. The HOS regulations contain an exemption that allows drivers using Department of Transportation-approved sleeper berth equipment to accumulate the required 8 consecutive hours off duty resting in a sleeper berth in two separate periods totaling 8 hours (neither period to be less than 2 hours).

The findings of this study show that truckdrivers with split sleep patterns were obtaining about 8 hours of sleep in a 24-hour time period; however, they obtained it in segments, on average of 4 hours at a time. Research, not available at the time the regulations were drafted by the Interstate Commerce Commission, has shown that sleep accumulated in short time blocks is less refreshing than sleep accumulated in one long time period.[19] Other research indicates that "...the more sleep is disturbed or reduced, for whatever reason, the more likely an individual will inadvertently slip into sleep."[20] A review of police accident reports has also demonstrated that decrements in performance occur earlier for drivers using sleeper berths (or drivers

---

[19] Dinges, D.F. 1989. The nature of sleepiness: causes, contexts, and consequences. In: Stunkard, A.J.; Baum, A. Perspectives in behavioral medicine: eating, sleeping, and sex. Hillsdale, NJ: Lawrence Erblaum Associates: 147-179. Chapter 9 (p. 147).

[20] (a) Mitler and others (1988, p. 107). (b) Rosekind, M.R.; Gander, P.H.; Connell, L.J.; Co, E.L. 1994. Crew factors in flight operations X: alertness management in flight operations. NASA/FAA Technical Memorandum DOT/FAA/RD-93/18.

with split sleep patterns) than for other drivers. The same research determined that split-shift, sleeper berth use (that is, driving without an 8-hour consecutive rest period) increased the risk of fatality more than two-fold. Sleep duration has been found to be as important to the recovery of performance abilities as is the quality of sleep experience.[21] Of the drivers for whom information on duty hours was available, 19 of 26 drivers with split sleep patterns (73 percent) had slept in a sleeper berth.

In drafting its original regulations, the Interstate Commerce Commission (ICC) noted the lack of scientific evidence about the nature of fatigue. The ICC was clearly frustrated at being unable to base its regulations on an empirical understanding of driver fatigue. Given what is now known about the inferior nature of split sleep patterns, it is unclear that the ICC would have permitted sleeper berth drivers to divide their required 8-hour off-duty period into two segments. Although the Safety Board encourages the use of sleeper berths for strategic napping and recognizes that sleeper berths may allow for continuous sleep, truckdrivers should not be encouraged or permitted to split their sleep. The current hours-of-service regulations do not permit drivers who sleep at a residence or in a motel to split their sleep periods. This exemption applies only to drivers who use sleeper berths. The Safety Board understands that in 1937, when these regulations were written, economic considerations required that freight move continuously—to keep produce and dairy products from spoiling, for example. However, the advent of refrigerated trucks eliminated concerns about food spoilage. The Board is also aware that the trucking industry wanted the flexibility provided by having drivers rest in their sleeper berths while waiting for other tasks to be completed (such as loading of tanks with crude oil). This would enable drivers to begin driving as soon as the tasks were completed and to drive for at least the time that they spent resting in their berths.

Although the Board is aware of the importance of just-in-time deliveries to the economic well-being of the manufacturing industry, the Board does not believe that this flexibility should be permitted at the expense of safety. The Safety Board is not aware of any physiological or laboratory research regarding the effect of split sleep patterns on performance; however, the Board's analysis has shown that the length of the most recent sleep period is the most important factor in determining fatigue and that the continuous nature of that sleep also is very important. Consequently, the Safety Board is asking the Federal Highway Administration to complete rulemaking within 2 years to eliminate 49 CFR 395.1 paragraph (h), which allows drivers with sleeper berth equipment to cumulate the 8 hours of off-duty time in two separate periods.

---

[21] Hertz, R.P. 1988. Tractor-trailer driver fatality: the role of nonconsecutive rest in a sleeper berth. Accident Analysis and Prevention. 20(6): 431-439.

Therefore, as a result of this study, the National Transportation Safety Board recommends that the Commercial Vehicle Safety Alliance:

> In cooperation with the Federal Highway Administration, the Professional Truck Driver Institute of America, the American Trucking Associations Inc., and the National Private Truck Council, develop and disseminate, in consultation with the U.S. Department of Transportation Human Factors Coordinating Committee, a training and education module to inform truckdrivers of the hazards of driving while fatigued. It should include information about the need for an adequate amount of quality sleep, strategies for avoiding sleep loss such as strategic napping, consideration of the behavioral and physiological consequences of sleepiness, and an awareness that sleep can occur suddenly and without warning to all drivers regardless of their age or experience. (Class II, Priority Action) (H-95-5)

Also as a result of the study, the Safety Board issued safety recommendations to the Federal Highway Administration, the Professional Truck Driver Institute of America, the American Trucking Associations Inc., the National Private Truck Council, the Independent Truck Owner Operators, the Owner-Operator Independent Driver's Association, the International Brotherhood of Teamsters, and the National Industrial Transportation League.

The National Transportation Safety Board is an independent Federal agency with the statutory responsibility "...to promote transportation safety by conducting independent accident investigations and by formulating safety improvement recommendations" (Public Law 93-633). The Safety Board is vitally interested in any actions taken as a result of its safety recommendations and would appreciate a response from you regarding action taken or contemplated with respect to the recommendation in this letter. Please refer to Safety Recommendation H-95-5 in your reply.

Chairman HALL and Members HAMMERSCHMIDT and FRANCIS concurred in this recommendation.

By: Jim Hall
Chairman

L08578A

National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: February 7, 1995

In reply refer to: H-95-5

Honorable Rodney E. Slater
Administrator
Federal Highway Administration
Washington, D.C. 20590

A Safety Board analysis of Fatal Accident Reporting System (FARS) data indicates that in 1993 there were 3,311 heavy trucks involved in 3,169 fatal accidents. In these accidents, 3,783 persons died (432 were occupants of the heavy trucks).[1] Research has suggested that truckdriver fatigue may be a contributing factor in as many as 30 to 40 percent of all heavy truck accidents.[2] In 1990, the Safety Board completed a study of 182 heavy truck accidents that were fatal to the truckdriver.[3] These 182 accidents were a census of the heavy truck accidents that were fatal to the driver in the eight States that participated. The primary purpose in investigating fatal-to-the-driver heavy truck accidents was to assess the role of alcohol and other drugs in these accidents. The study found, however, that the most frequently cited probable cause was fatigue. The Board believes that the 31 percent incidence of fatigue in fatal-to-the-truckdriver accidents found in the 1990 study represents a valid estimate of the portion of fatal-to-the-driver heavy truck accidents that are fatigue-related. Little data are available to estimate the incidence of fatigue in the less severe heavy truck accidents.

[1] For this analysis, the Board defined a heavy truck as one >26,000 pounds gross vehicle weight.

[2] (a) Knipling, Ronald R.; Wang, Jing-Shiarn. 1994. Crashes and fatalities related to driver drowsiness/fatigue. Research Note. Washington, DC: U.S. Department of Transportation, National Highway Traffic Safety Administration. November. (b) Ryder, Andrew, ed. 1990. A system in need of overhaul. In: Driver fatigue, Part 1. Heavy duty trucking. September: 69-73.

[3] National Transportation Safety Board. 1990. Fatigue, alcohol, other drugs, and medical factors in fatal-to-the-driver heavy truck crashes. Safety Study NTSB/SS-90/01. Washington, DC.

Because of the significant number of heavy truck-related fatalities and the role of fatigue in such accidents, the Board initiated a study of single-vehicle heavy truck accidents to examine the role of specific factors that affect driver fatigue, such as drivers' patterns of duty and sleep, in heavy truck accidents and to determine potential remedial actions. Most research of the factors associated with fatigue involve laboratory studies that examine the effect of sleep deprivation on the operator's performance of specific tasks, such as controlled driving in which various physiological measures are documented, or involve retrospective reviews of accident records, such as police records, which contain limited data and are not designed to assess the role of human performance factors in fatigue-related accidents. The Safety Board is in a unique position to study the role of human performance factors that contribute to fatigue-related accidents. Accident investigation is the primary function of the Board, and it has been examining the role of human performance factors (and fatigue in particular) in accidents in all transportation modes for many years. Therefore, this study[4] of actual accidents provides a unique opportunity to examine the factors that contribute to fatigue-related accidents.

Because the purpose of the Board's study was to examine the factors that affect driver fatigue and not the statistical incidence of fatigue, the Board specifically selected truck accidents that were likely to include fatigue-related accidents; that is, single-vehicle accidents that tend to occur at night. The Board desired to obtain approximately an equal number of fatigue-related and nonfatigue-related accidents through its notification process to examine the differences between the two groups. From September 1992 through June 1993, the Board was notified by authorities in the States of Alabama, California, Georgia, New Jersey, North Carolina, and Texas[5] of single-vehicle accidents. During this period, the Board accepted sequentially for investigation, with no prejudgment of fatigue involvement, those accidents that occurred within a reasonable driving distance from the Board's regional offices and in which the vehicle was available for examination and the driver was available to be interviewed.

The Board was specifically interested in obtaining accurate information regarding the truckdrivers' duty and sleep patterns for the 96 hours preceding the accident; therefore, the Board limited the accidents to those in which the driver survived and was available to be interviewed by the Board's investigators to reconstruct the previous 96 hours. The Board did not rely solely on the drivers' official log books because of concern that inaccurate or incomplete information might have been recorded and because total sleep time is not required to be reported.

---

[4] National Transportation Safety Board. 1995. Factors that affect fatigue in heavy truck accidents. Volume 1: analysis. Safety Study NTSB/SS-95/01. Washington, DC.

[5] According to FARS data, in 1992 about 27 percent of fatal accidents involving large trucks in the United States occurred in these six States.

The Safety Board investigated 113 single-vehicle heavy truck accidents in which the driver survived. However, because the 96-hour duty/sleep history that was required for the study was not available for 6 drivers, the 6 accidents in which these drivers were involved were not included in the study. The study, therefore, analyzes data from 107 single-vehicle heavy truck accidents.[6]

The Board examined several measures of duty time, driving time, awake time, and sleeping time for the drivers. These measures included (1) the number of hours awake, driving, on duty, and sleeping in the 24-, 48-, 72-, and 96-hour periods before the accident, (2) the number of hours driving since the driver had last slept, (3) the number of hours driving in the period most recent to the accident, (4) the number of hours on duty prior to the accident (including nondriving activities such as loading and unloading cargo, truck inspections, paperwork, calling dispatchers, and waiting at terminals), (5) the number of hours since the driver had last slept, and (6) the number of hours slept in the sleep period most recent to the accident.[7] These measures were taken from the 96-hour logs that were reconstructed from the Safety Board investigators' interviews with the drivers.

The Board also examined the drivers' duty/sleep patterns for the 96-hour period before the accident. The Board established five measures of the drivers' duty/sleep patterns. The five dichotomous (yes/no) measures included irregular duty, irregular sleep, both irregular duty and sleep, regular duty and sleep, and regular sleep with nonclassifiable duty.[8] These five measures are mutually exclusive. The Board also identified three other schedule-related measures that could occur for a driver with either regular or irregular duty/sleep patterns. They include inverted duty/sleep, split sleep patterns, and exceeded hours-of-service limits (exceeded HOS limits).

A total of 21 measures were used to characterize drivers' patterns and amounts of duty and sleep in the 96 hours prior to the accident.[9] Of the 107 drivers, the complete set of duty/sleep measures could not be computed for 20 drivers; hence, data from only 87 drivers were available for analysis (51 were involved in fatigue-related

---

[6] Volume 2 of this study (NTSB/SS-95/02) contains the briefs of the 107 accidents investigated by the Safety Board.

[7] For purposes of discussion in this study, these measures have been termed "duty/sleep time measures."

[8] If a driver did not have at least three consecutive start times, his duty hours were considered "nonclassifiable."

[9] The majority of the single-vehicle accidents in the Safety Board's sample occurred between 2 and 8 a.m. (53 percent), and an even higher percentage of the accidents that were determined to be fatigue-related occurred during these same hours (75 percent). Time of day was not included as one of the 21 measures because of the inherent bias in the sample of cases; that is, single-vehicle accidents are likely to occur at night when traffic is light or sparse.

accidents, 36 were not). As would be expected, the driving and duty times of the 20 excluded drivers were less than those of the 87 drivers who had not had days off. Eleven of the 20 excluded drivers were involved in fatigue-related accidents, and the remaining 9 drivers were involved in nonfatigue-related accidents.

A multiple discriminant analysis[10] was performed to simultaneously evaluate the relationship of a set of 18 predictor measures[11] to the groupings of accidents established by investigators' determination of probable cause (fatigue-related and nonfatigue-related accidents). In the present case, discriminant analysis provides a means of simultaneously examining the capacity of the interrelated sleep, duty, and scheduling measures to classify an accident as either fatigue-related or nonfatigue-related. The combination of measures resulting from the application of the discriminant analysis to the Board's 87 accidents was able to correctly classify 94.4 percent of the nonfatigue-related accidents and 80.4 percent of the fatigue-related accidents—a very high rate of successful classification.[12]

The results of the discriminant analysis indicate that the most critical measures in predicting fatigue-related accidents in the Safety Board's sample are the duration of the most recent sleep period, the amount of sleep in the past 24 hours, and split sleep patterns. It is not surprising that sleep factors rated high in this analysis given the results of extensive scientific research in this area. However, the Board believes that it is noteworthy in this unique sample of actual accidents that factors that affect the ability to obtain adequate sleep, such as irregular duty/sleep and inverted schedules (which are often assumed to be closely associated with fatigue), ranked well below the factors that affect the quantity and quality of sleep.[13]

The truckdrivers in fatigue-related accidents in this sample obtained on average 5.5 hours of sleep in the last sleep period prior to the accident. This is 1.4 hours less than the 6.9 hours they reported needing to feel rested and 2.5 hours less than that obtained by drivers in nonfatigue-related accidents (8.0 hours of sleep in the last sleep period). The findings further indicate that the truckdrivers involved

---

[10] A description of discriminant analysis can be found in the following publication: Tabachnick, B.G.; Fidell, L.S. 1989. Using multivariate statistics. 2nd ed. New York: Harper & Row. 746 p.

[11] Because hours awake and hours asleep in the last 24 or 48 hours were complements of one another, only the time asleep measures were included in the analysis. Similarly, the scheduling measure of regular sleep/duty was not included because it is simply the complement of irregular duty/sleep. Thus, the set of predictors was reduced to 18 measures.

[12] Details of the discriminant analysis are contained in chapter 4 and appendix D of the study (NTSB/SS-95/01).

[13] Although the Safety Board examined single-vehicle accidents, there is no reason to believe that the factors that were associated with fatigue-related single-vehicle accidents would be any different in other kinds of accidents. The Board believes, therefore, that the results of this study can be generalized to the trucking population as a whole.

in fatigue-related accidents obtained about 2.4 hours less sleep in the 24-hour period before the accident than the drivers not involved in fatigue-related accidents (6.9 hours compared to 9.3 hours).

The data indicate that the mean time awake, but not on duty, for the drivers in the fatigue-related accidents was about 5.5 hours. This suggests that these drivers could have readily attained more than the mean of 5.5 hours of sleep during the last sleep period prior to the accident. However, the timing of the awake period may not have fit with the driving schedule to permit 8 hours continuous sleep in the last sleep period. Further, the drivers have a need to attend to family duties and other responsibilities. The fact that drivers in nonfatigue-related accidents also were awake about 5.5 hours while off duty (but still attained 8 hours sleep in the most recent sleep period prior to the accident) suggests that 5.5 hours is not an unreasonable period of time to be allocated to such needs. It appears, therefore, that if the driving or on-duty time is pushed to the maximum hours allowed, drivers will reduce the amount of time for sleep rather than the time needed to accomplish other duties and responsibilities.

Research indicates that the amount of sleep needed varies on an individual basis: "...for some it is 5 to 6 hours a night, for others it is...7 or 8 hours, and for still others it is 9 to 10 hours."[14] The Safety Board recognizes that all truckdrivers do not need 8 hours of sleep. However, responsible public policy dictates that drivers of heavy trucks be able to obtain adequate sleep between work assignments. Implementation of this policy, in the form of Federal regulations or industry procedures and practices, cannot generally address drivers on an individual basis. Thus, implementation of this policy must address the norm, which research has determined to be 8 hours—a fact noted by the ICC in 1937.[15] The results of this study support the need by the "average" driver for 8 continuous hours of sleep.

The Safety Board recognizes that regulations cannot assure that adequate sleep will be obtained. Nevertheless, the regulations can and must provide the opportunity to obtain an adequate amount of rest. However, the 8-hour off-duty requirement in the current regulations does not do so because it does not provide time for travel, eating, personal hygiene, and recreation. Further, depending on various factors, including the time of day, a driver may not be able to fall asleep immediately at the beginning of the 8-hour off-duty period. Because the results of this accident sample are unlikely to be substantially enhanced by any further research, these results provide a solid basis for sound policy decisions. The Board also recognizes that the inadequate sleep obtained may not be directly related to the

---

[14] Dinges, D.F. 1984. The nature and timing of sleep. Transactions & Studies of the College of Physicians of Philadelphia. Ser 5:6(3): 177-206 (p. 198).

[15] (a) Carskadon, M.S.; Dement, W.C. (1994). (b) Carskadon, Mary A., ed. 1993. Encyclopedia of sleep and dreaming. New York: Macmillan Publishing Company.

8-hour off-duty requirement in the HOS regulations. However, in the Safety Board's view, a minimum standard that does not provide for at least 8 hours of sleep is not responsible public policy and could be construed as condoning less than 8 hours of sleep as adequate, when the time needed for eating, hygiene, and recreation is considered. Therefore, the Board is asking the FHWA to complete rulemaking within 2 years to revise 49 CFR 395.1 to require sufficient rest provisions to enable drivers to obtain at least 8 continuous hours of sleep.

Given the results of the latest research and studies on fatigue and sleep issues, the Board believes that steps can be taken now to provide truckdrivers with the opportunity to obtain 8 hours of sleep and that the trucking industry can take a lead role in this effort. Therefore, the Safety Board believes that the trucking industry should incorporate into its scheduling practices and procedures the results of the latest research on fatigue and sleep issues, particularly that an 8-hour sleep need is the norm. The Safety Board believes that current scheduling practices can accommodate a change in the rest period without resulting in undue economic hardships. The Safety Board believes that the majority of trucking companies currently comply with the hours-of-service regulations and that an increase in the amount of off-duty time would not change the way they schedule their deliveries or require changes in the locations of terminals. The data in this sample show that the truckdrivers involved in nonfatigue-related accidents were typically on duty 9 hours a day. These drivers had sufficient time to obtain adequate sleep and, in fact, did obtain 8 hours of continuous sleep in their last sleep period.

The Safety Board recognizes that providing the opportunity to obtain adequate sleep will not assure that drivers actually obtain that sleep. The ICC recognized this in 1937, stating:

> We fully recognize that regulations of this kind cannot provide a complete answer to the problem of driver fatigue and its effect upon safety of operation. We have no control over the manner in which a driver may spend his time off duty, although some of his spare-time activities may tire him quite as much as any work would do. We can only emphasize, by this comment, the responsibility which is the driver's own to assure himself of adequate rest and sleep, in the time available for this purpose, to ensure the safety of his driving, and likewise the employer's responsibility to see that his drivers report for work in fit condition.

Although drivers have a responsibility to obtain adequate rest and sleep, they must first recognize that they need sleep. Many of the truckdrivers in the Safety Board's accident sample who were involved in fatigue-related accidents did not recognize that they were in need of sleep and believed that they were rested when they were not. Drivers in both fatigue-related and nonfatigue-related accidents rated themselves as being okay to fully alert before the accident. Further, about 80 percent

of the drivers involved in fatigue-related accidents rated the quality of their last sleep before the accident as good or excellent. Drivers in fatigue-related accidents received about 1.4 hours less sleep than they reported needing to feel rested. Research has indicated that people "...have a limited ability to predict the onset of sleep...[and that]...subjects certainly do fall asleep at times when they think sleep is highly unlikely."[16]

"Inadequate sleep, even as little as 1 or 2 hours less than usual sleep, can greatly exaggerate the tendency for error during the time zones of vulnerability (1 to about 8 a.m. and 2 to roughly 6 p.m.)."[17] The majority of the accidents in this sample occurred between 2 and 8 a.m. (53 percent), and an even higher percentage of the accidents that were found to be fatigue-related occurred during these same hours (75 percent). Driving at night, as many truckdrivers must do, is complicated by the effects of circadian rhythms. Thus, a sleep deprived person driving at night is in the highest risk situation—a risk that many drivers may not be aware of or recognize.

Modifying the regulations to increase the off-duty period will not, by itself, eliminate the problem of truckdriver fatigue. Educating transportation employees about the effects of fatigue, in the Safety Board's view, is a vitally important component of overall efforts to combat fatigue in transportation. The Board recognizes that there is a considerable amount of research underway that could eventually be used to develop or modify programs designed to educate operators of heavy trucks and other industry personnel, in particular management, about the importance of sleep loss and other factors in fatigue-related accidents. However, the Board believes that this study and other research have provided important information that could be provided now to truckdrivers and management about factors leading to fatigue and possible strategies to combat fatigue. In addition to studies discussed above, the NASA Ames Fatigue Countermeasures Program stands out as demonstrating some especially effective countermeasures. This program, which has been underway since 1980, has addressed strategic napping as a preventive strategy and an operational countermeasure to combat sleep loss, circadian disruption, and fatigue that occur as a result of multiple time zone changes, and extended, irregular duty schedules in flight operations.[18] The researchers found that there is scientific evidence showing that as a preventive strategy, napping before

---

[16] Itoi, A.; Cilveti, R.; Voth, M.; and others. 1993. Can drivers avoid falling asleep at the wheel? Relationship between awareness of sleepiness and ability to predict sleep onset. Washington, DC: AAA Foundation for Traffic Safety (p. 25). 33 p.

[17] Mitler, M.; Carskadon, M.A.; Czeisler, C.A.; and others. 1988. Catastrophes, sleep and public policy: consensus report. Sleep. 11(1): 100-109.

[18] Rosekind, Mark R.; Graeber, R. Curtis; Dinges, David F.; and others. 1993. Crew factors in flight operations. IX: Effects of planned cockpit rest on crew performance and alertness in long-haul flight operations. NASA Technical Memorandum 108839. DOT/FAA/92/24. Washington, DC.

fatigue develops is quite effective in an operational setting. A single nap of about 45 minutes in duration prior to a night without sleep can prevent significant loss of performance capability and fatigue throughout the night. The Safety Board agrees that the use of naps as a means to prevent fatigue prior to its onset is a worthwhile countermeasure. The Board cautions, however, that these naps should be a supplement to, not a replacement for, one continuous 8-hour sleep period.

Therefore, the Safety Board believes that the Federal Highway Administration, the Professional Truck Driver Institute of America, the American Trucking Associations, Inc., and the Commercial Vehicle Safety Alliance, and the National Private Truck Council in consultation with the U.S. Department of Transportation Human Factors Coordinating Committee should cooperatively develop and disseminate a training and education module that includes information about the need for an adequate amount of quality sleep, strategies for avoiding sleep loss such as strategic napping, consideration of the behavioral and physiological consequences of sleepiness, and an awareness that sleep can occur suddenly and without warning to all drivers regardless of their age or experience. Because of the strides that have been made in this area in the other transportation modes, particularly in aviation by NASA Ames, the Board urges the FHWA to consult the other modal administrations before developing this training and education module.

Another measure that was relatively highly correlated with fatigue was split sleep patterns. Split sleep patterns also ranked fifth in importance in discriminating between long-haul and short-haul operations. The HOS regulations contain an exemption that allows drivers using Department of Transportation-approved sleeper berth equipment to accumulate the required 8 consecutive hours off duty resting in a sleeper berth in two separate periods totaling 8 hours (neither period to be less than 2 hours).

The findings of this study show that truckdrivers with split sleep patterns were obtaining about 8 hours of sleep in a 24-hour time period; however, they obtained it in segments, on average of 4 hours at a time. Research, not available at the time the regulations were drafted by the Interstate Commerce Commission, has shown that sleep accumulated in short time blocks is less refreshing than sleep accumulated in one long time period.[19] Other research indicates that "...the more sleep is disturbed or reduced, for whatever reason, the more likely an individual will inadvertently slip into sleep."[20] A review of police accident reports has also demonstrated that decrements in performance occur earlier for drivers using sleeper berths (or drivers

---

[19] Dinges, D.F. 1989. The nature of sleepiness: causes, contexts, and consequences. In: Stunkard, A.J.; Baum, A. Perspectives in behavioral medicine: eating, sleeping, and sex. Hillsdale, NJ: Lawrence Erblaum Associates: 147-179. Chapter 9 (p. 147).

[20] (a) Mitler and others (1988, p. 107). (b) Rosekind, M.R.; Gander, P.H.; Connell, L.J.; Co, E.L. 1994. Crew factors in flight operations X: alertness management in flight operations. NASA/FAA Technical Memorandum DOT/FAA/RD-93/18.

with split sleep patterns) than for other drivers. The same research determined that split-shift, sleeper berth use (that is, driving without an 8-hour consecutive rest period) increased the risk of fatality more than two-fold. Sleep duration has been found to be as important to the recovery of performance abilities as is the quality of sleep experience.[21] Of the drivers for whom information on duty hours was available, 19 of 26 drivers with split sleep patterns (73 percent) had slept in a sleeper berth.

In drafting its original regulations, the Interstate Commerce Commission (ICC) noted the lack of scientific evidence about the nature of fatigue. The ICC was clearly frustrated at being unable to base its regulations on an empirical understanding of driver fatigue. Given what is now known about the inferior nature of split sleep patterns, it is unclear that the ICC would have permitted sleeper berth drivers to divide their required 8-hour off-duty period into two segments. Although the Safety Board encourages the use of sleeper berths for strategic napping and recognizes that sleeper berths may allow for continuous sleep, truckdrivers should not be encouraged or permitted to split their sleep. The current hours-of-service regulations do not permit drivers who sleep at a residence or in a motel to split their sleep periods. This exemption applies only to drivers who use sleeper berths. The Safety Board understands that in 1937, when these regulations were written, economic considerations required that freight move continuously—to keep produce and dairy products from spoiling, for example. However, the advent of refrigerated trucks eliminated concerns about food spoilage. The Board is also aware that the trucking industry wanted the flexibility provided by having drivers rest in their sleeper berths while waiting for other tasks to be completed (such as loading of tanks with crude oil). This would enable drivers to begin driving as soon as the tasks were completed and to drive for at least the time that they spent resting in their berths.

Although the Board is aware of the importance of just-in-time deliveries to the economic well-being of the manufacturing industry, the Board does not believe that this flexibility should be permitted at the expense of safety. The Safety Board is not aware of any physiological or laboratory research regarding the effect of split sleep patterns on performance; however, the Board's analysis has shown that the length of the most recent sleep period is the most important factor in determining fatigue and that the continuous nature of that sleep also is very important. Consequently, the Safety Board is asking the Federal Highway Administration to complete rulemaking within 2 years to eliminate 49 CFR 395.1 paragraph (h), which allows drivers with sleeper berth equipment to cumulate the 8 hours of off-duty time in two separate periods.

---

[21] Hertz, R.P. 1988. Tractor-trailer driver fatality: the role of nonconsecutive rest in a sleeper berth. Accident Analysis and Prevention. 20(6): 431-439

Therefore, as a result of this study, the National Transportation Safety Board recommends that the Federal Highway Administration:

> In cooperation with the Professional Truck Driver Institute of America, the American Trucking Associations, Inc., the Commercial Vehicle Safety Alliance, and the National Private Truck Council, develop and disseminate, in consultation with the U.S. Department of Transportation Human Factors Coordinating Committee, a training and education module to inform truckdrivers of the hazards of driving while fatigued. It should include information about the need for an adequate amount of quality sleep, strategies for avoiding sleep loss such as strategic napping, consideration of the behavioral and physiological consequences of sleepiness, and an awareness that sleep can occur suddenly and without warning to all drivers regardless of their age or experience. (Class II, Priority Action) (H-95-5)

Also as a result of the study, the Safety Board issued safety recommendations to the Professional Truck Driver Institute of America, the American Trucking Associations, Inc., the Commercial Vehicle Safety Alliance, the National Private Truck Council, the Independent Truck Owner Operators, the Owner-Operator Independent Driver's Association, the International Brotherhood of Teamsters, and the National Industrial Transportation League.

Chairman HALL and Members HAMMERSCHMIDT and FRANCIS concurred in this recommendation.

By: Jim Hall
Chairman

Log 578A

National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: February 7, 1995

In reply refer to: H-95-5

Mr. Gene Bergoffen, CAE
President and CEO
National Private Truck Council
Suite 600, 66 Canal Center Plaza
Alexandria, Virginia 22314

A Safety Board analysis of Fatal Accident Reporting System (FARS) data indicates that in 1993 there were 3,311 heavy trucks involved in 3,169 fatal accidents. In these accidents, 3,783 persons died (432 were occupants of the heavy trucks).[1] Research has suggested that truckdriver fatigue may be a contributing factor in as many as 30 to 40 percent of all heavy truck accidents.[2] In 1990, the Safety Board completed a study of 182 heavy truck accidents that were fatal to the truckdriver.[3] These 182 accidents were a census of the heavy truck accidents that were fatal to the driver in the eight States that participated. The primary purpose in investigating fatal-to-the-driver heavy truck accidents was to assess the role of alcohol and other drugs in these accidents. The study found, however, that the most frequently cited probable cause was fatigue. The Board believes that the 31 percent incidence of fatigue in fatal-to-the-truckdriver accidents found in the 1990 study represents a valid estimate of the portion of fatal-to-the-driver heavy truck accidents that are fatigue-related. Little data are available to estimate the incidence of fatigue in the less severe heavy truck accidents.

[1] For this analysis, the Board defined a heavy truck as one >26,000 pounds gross vehicle weight.

[2] (a) Knipling, Ronald R.; Wang, Jing-Shiarn. 1994. Crashes and fatalities related to driver drowsiness/fatigue. Research Note. Washington, DC: U.S. Department of Transportation, National Highway Traffic Safety Administration. November. (b) Ryder, Andrew, ed. 1990. A system in need of overhaul. In: Driver fatigue, Part 1. Heavy duty trucking. September: 69-73.

[3] National Transportation Safety Board. 1990. Fatigue, alcohol, other drugs, and medical factors in fatal-to-the-driver heavy truck crashes. Safety Study NTSB/SS-90/01. Washington, DC.

Because of the significant number of heavy truck-related fatalities and the role of fatigue in such accidents, the Board initiated a study of single-vehicle heavy truck accidents to examine the role of specific factors that affect driver fatigue, such as drivers' patterns of duty and sleep, in heavy truck accidents and to determine potential remedial actions. Most research of the factors associated with fatigue involve laboratory studies that examine the effect of sleep deprivation on the operator's performance of specific tasks, such as controlled driving in which various physiological measures are documented, or involve retrospective reviews of accident records, such as police records, which contain limited data and are not designed to assess the role of human performance factors in fatigue-related accidents. The Safety Board is in a unique position to study the role of human performance factors that contribute to fatigue-related accidents. Accident investigation is the primary function of the Board, and it has been examining the role of human performance factors (and fatigue in particular) in accidents in all transportation modes for many years. Therefore, this study[4] of actual accidents provides a unique opportunity to examine the factors that contribute to fatigue-related accidents.

Because the purpose of the Board's study was to examine the factors that affect driver fatigue and not the statistical incidence of fatigue, the Board specifically selected truck accidents that were likely to include fatigue-related accidents; that is, single-vehicle accidents that tend to occur at night. The Board desired to obtain approximately an equal number of fatigue-related and nonfatigue-related accidents through its notification process to examine the differences between the two groups. From September 1992 through June 1993, the Board was notified by authorities in the States of Alabama, California, Georgia, New Jersey, North Carolina, and Texas[5] of single-vehicle accidents. During this period, the Board accepted sequentially for investigation, with no prejudgment of fatigue involvement, those accidents that occurred within a reasonable driving distance from the Board's regional offices and in which the vehicle was available for examination and the driver was available to be interviewed.

The Board was specifically interested in obtaining accurate information regarding the truckdrivers' duty and sleep patterns for the 96 hours preceding the accident; therefore, the Board limited the accidents to those in which the driver survived and was available to be interviewed by the Board's investigators to reconstruct the previous 96 hours. The Board did not rely solely on the drivers' official log books because of concern that inaccurate or incomplete information might have been recorded and because total sleep time is not required to be reported.

---

[4] National Transportation Safety Board. 1995. Factors that affect fatigue in heavy truck accidents. Volume 1: analysis. Safety Study NTSB/SS-95/01. Washington, DC.

[5] According to FARS data, in 1992 about 27 percent of fatal accidents involving large trucks in the United States occurred in these six States.

The Safety Board investigated 113 single-vehicle heavy truck accidents in which the driver survived. However, because the 96-hour duty/sleep history that was required for the study was not available for 6 drivers, the 6 accidents in which these drivers were involved were not included in the study. The study, therefore, analyzes data from 107 single-vehicle heavy truck accidents.[6]

The Board examined several measures of duty time, driving time, awake time, and sleeping time for the drivers. These measures included (1) the number of hours awake, driving, on duty, and sleeping in the 24-, 48-, 72-, and 96-hour periods before the accident, (2) the number of hours driving since the driver had last slept, (3) the number of hours driving in the period most recent to the accident, (4) the number of hours on duty prior to the accident (including nondriving activities such as loading and unloading cargo, truck inspections, paperwork, calling dispatchers, and waiting at terminals), (5) the number of hours since the driver had last slept, and (6) the number of hours slept in the sleep period most recent to the accident.[7] These measures were taken from the 96-hour logs that were reconstructed from the Safety Board investigators' interviews with the drivers.

The Board also examined the drivers' duty/sleep patterns for the 96-hour period before the accident. The Board established five measures of the drivers' duty/sleep patterns. The five dichotomous (yes/no) measures included irregular duty, irregular sleep, both irregular duty and sleep, regular duty and sleep, and regular sleep with nonclassifiable duty.[8] These five measures are mutually exclusive. The Board also identified three other schedule-related measures that could occur for a driver with either regular or irregular duty/sleep patterns. They include inverted duty/sleep, split sleep patterns, and exceeded hours-of-service limits (exceeded HOS limits).

A total of 21 measures were used to characterize drivers' patterns and amounts of duty and sleep in the 96 hours prior to the accident.[9] Of the 107 drivers, the complete set of duty/sleep measures could not be computed for 20 drivers; hence, data from only 87 drivers were available for analysis (51 were involved in fatigue-related

---

[6] Volume 2 of this study (NTSB/SS-95/02) contains the briefs of the 107 accidents investigated by the Safety Board.

[7] For purposes of discussion in this study, these measures have been termed "duty/sleep time measures."

[8] If a driver did not have at least three consecutive start times, his duty hours were considered "nonclassifiable."

[9] The majority of the single-vehicle accidents in the Safety Board's sample occurred between 2 and 8 a.m. (53 percent), and an even higher percentage of the accidents that were determined to be fatigue-related occurred during these same hours (75 percent). Time of day was not included as one of the 21 measures because of the inherent bias in the sample of cases; that is, single-vehicle accidents are likely to occur at night when traffic is light or sparse.

accidents, 36 were not). As would be expected, the driving and duty times of the 20 excluded drivers were less than those of the 87 drivers who had not had days off. Eleven of the 20 excluded drivers were involved in fatigue-related accidents, and the remaining 9 drivers were involved in nonfatigue-related accidents.

A multiple discriminant analysis[10] was performed to simultaneously evaluate the relationship of a set of 18 predictor measures[11] to the groupings of accidents established by investigators' determination of probable cause (fatigue-related and nonfatigue-related accidents). In the present case, discriminant analysis provides a means of simultaneously examining the capacity of the interrelated sleep, duty, and scheduling measures to classify an accident as either fatigue-related or nonfatigue-related. The combination of measures resulting from the application of the discriminant analysis to the Board's 87 accidents was able to correctly classify 94.4 percent of the nonfatigue-related accidents and 80.4 percent of the fatigue-related accidents—a very high rate of successful classification.[12]

The results of the discriminant analysis indicate that the most critical measures in predicting fatigue-related accidents in the Safety Board's sample are the duration of the most recent sleep period, the amount of sleep in the past 24 hours, and split sleep patterns. It is not surprising that sleep factors rated high in this analysis given the results of extensive scientific research in this area. However, the Board believes that it is noteworthy in this unique sample of actual accidents that factors that affect the ability to obtain adequate sleep, such as irregular duty/sleep and inverted schedules (which are often assumed to be closely associated with fatigue), ranked well below the factors that affect the quantity and quality of sleep.[13]

The truckdrivers in fatigue-related accidents in this sample obtained on average 5.5 hours of sleep in the last sleep period prior to the accident. This is 1.4 hours less than the 6.9 hours they reported needing to feel rested and 2.5 hours less than that obtained by drivers in nonfatigue-related accidents (8.0 hours of sleep in the last sleep period). The findings further indicate that the truckdrivers involved

---

[10] A description of discriminant analysis can be found in the following publication: Tabachnick, B.G.; Fidell, L.S. 1989. Using multivariate statistics. 2nd ed. New York: Harper & Row. 746 p.

[11] Because hours awake and hours asleep in the last 24 or 48 hours were complements of one another, only the time asleep measures were included in the analysis. Similarly, the scheduling measure of regular sleep/duty was not included because it is simply the complement of irregular duty/sleep. Thus, the set of predictors was reduced to 18 measures.

[12] Details of the discriminant analysis are contained in chapter 4 and appendix D of the study (NTSB/SS-95/01).

[13] Although the Safety Board examined single-vehicle accidents, there is no reason to believe that the factors that were associated with fatigue-related single-vehicle accidents would be any different in other kinds of accidents. The Board believes, therefore, that the results of this study can be generalized to the trucking population as a whole.

in fatigue-related accidents obtained about 2.4 hours less sleep in the 24-hour period before the accident than the drivers not involved in fatigue-related accidents (6.9 hours compared to 9.3 hours).

The data indicate that the mean time awake, but not on duty, for the drivers in the fatigue-related accidents was about 5.5 hours. This suggests that these drivers could have readily attained more than the mean of 5.5 hours of sleep during the last sleep period prior to the accident. However, the timing of the awake period may not have fit with the driving schedule to permit 8 hours continuous sleep in the last sleep period. Further, the drivers have a need to attend to family duties and other responsibilities. The fact that drivers in nonfatigue-related accidents also were awake about 5.5 hours while off duty (but still attained 8 hours sleep in the most recent sleep period prior to the accident) suggests that 5.5 hours is not an unreasonable period of time to be allocated to such needs. It appears, therefore, that if the driving or on-duty time is pushed to the maximum hours allowed, drivers will reduce the amount of time for sleep rather than the time needed to accomplish other duties and responsibilities.

Research indicates that the amount of sleep needed varies on an individual basis: "...for some it is 5 to 6 hours a night, for others it is...7 or 8 hours, and for still others it is 9 to 10 hours."[14] The Safety Board recognizes that all truckdrivers do not need 8 hours of sleep. However, responsible public policy dictates that drivers of heavy trucks be able to obtain adequate sleep between work assignments. Implementation of this policy, in the form of Federal regulations or industry procedures and practices, cannot generally address drivers on an individual basis. Thus, implementation of this policy must address the norm, which research has determined to be 8 hours—a fact noted by the ICC in 1937.[15] The results of this study support the need by the "average" driver for 8 continuous hours of sleep.

The Safety Board recognizes that regulations cannot assure that adequate sleep will be obtained. Nevertheless, the regulations can and must provide the opportunity to obtain an adequate amount of rest. However, the 8-hour off-duty requirement in the current regulations does not do so because it does not provide time for travel, eating, personal hygiene, and recreation. Further, depending on various factors, including the time of day, a driver may not be able to fall asleep immediately at the beginning of the 8-hour off-duty period. Because the results of this accident sample are unlikely to be substantially enhanced by any further research, these results provide a solid basis for sound policy decisions. The Board also recognizes that the inadequate sleep obtained may not be directly related to the

---

[14] Dinges, D.F. 1984. The nature and timing of sleep. Transactions & Studies of the College of Physicians of Philadelphia. Ser.5:6(3): 177-206 (p. 198).

[15] (a) Carskadon, M.S.; Dement, W.C. (1994). (b) Carskadon, Mary A., ed. 1993. Encyclopedia of sleep and dreaming. New York: Macmillan Publishing Company.

8-hour off-duty requirement in the HOS regulations. However, in the Safety Board's view, a minimum standard that does not provide for at least 8 hours of sleep is not responsible public policy and could be construed as condoning less than 8 hours of sleep as adequate, when the time needed for eating, hygiene, and recreation is considered. Therefore, the Board is asking the FHWA to complete rulemaking within 2 years to revise 49 CFR 395.1 to require sufficient rest provisions to enable drivers to obtain at least 8 continuous hours of sleep.

Given the results of the latest research and studies on fatigue and sleep issues, the Board believes that steps can be taken now to provide truckdrivers with the opportunity to obtain 8 hours of sleep and that the trucking industry can take a lead role in this effort. Therefore, the Safety Board believes that the trucking industry should incorporate into its scheduling practices and procedures the results of the latest research on fatigue and sleep issues, particularly that an 8-hour sleep need is the norm. The Safety Board believes that current scheduling practices can accommodate a change in the rest period without resulting in undue economic hardships. The Safety Board believes that the majority of trucking companies currently comply with the hours-of-service regulations and that an increase in the amount of off-duty time would not change the way they schedule their deliveries or require changes in the locations of terminals. The data in this sample show that the truckdrivers involved in nonfatigue-related accidents were typically on duty 9 hours a day. These drivers had sufficient time to obtain adequate sleep and, in fact, did obtain 8 hours of continuous sleep in their last sleep period.

The Safety Board recognizes that providing the opportunity to obtain adequate sleep will not assure that drivers actually obtain that sleep. The ICC recognized this in 1937, stating:

> We fully recognize that regulations of this kind cannot provide a complete answer to the problem of driver fatigue and its effect upon safety of operation. We have no control over the manner in which a driver may spend his time off duty, although some of his spare-time activities may tire him quite as much as any work would do. We can only emphasize, by this comment, the responsibility which is the driver's own to assure himself of adequate rest and sleep, in the time available for this purpose, to ensure the safety of his driving, and likewise the employer's responsibility to see that his drivers report for work in fit condition.

Although drivers have a responsibility to obtain adequate rest and sleep, they must first recognize that they need sleep. Many of the truckdrivers in the Safety Board's accident sample who were involved in fatigue-related accidents did not recognize that they were in need of sleep and believed that they were rested when they were not. Drivers in both fatigue-related and nonfatigue-related accidents rated themselves as being okay to fully alert before the accident. Further, about 80 percent

of the drivers involved in fatigue-related accidents rated the quality of their last sleep before the accident as good or excellent. Drivers in fatigue-related accidents received about 1.4 hours less sleep than they reported needing to feel rested. Research has indicated that people "...have a limited ability to predict the onset of sleep...[and that]...subjects certainly do fall asleep at times when they think sleep is highly unlikely."[16]

"Inadequate sleep, even as little as 1 or 2 hours less than usual sleep, can greatly exaggerate the tendency for error during the time zones of vulnerability (1 to about 8 a.m. and 2 to roughly 6 p.m.)."[17] The majority of the accidents in this sample occurred between 2 and 8 a.m. (53 percent), and an even higher percentage of the accidents that were found to be fatigue-related occurred during these same hours (75 percent). Driving at night, as many truckdrivers must do, is complicated by the effects of circadian rhythms. Thus, a sleep deprived person driving at night is in the highest risk situation—a risk that many drivers may not be aware of or recognize.

Modifying the regulations to increase the off-duty period will not, by itself, eliminate the problem of truckdriver fatigue. Educating transportation employees about the effects of fatigue, in the Safety Board's view, is a vitally important component of overall efforts to combat fatigue in transportation. The Board recognizes that there is a considerable amount of research underway that could eventually be used to develop or modify programs designed to educate operators of heavy trucks and other industry personnel, in particular management, about the importance of sleep loss and other factors in fatigue-related accidents. However, the Board believes that this study and other research have provided important information that could be provided now to truckdrivers and management about factors leading to fatigue and possible strategies to combat fatigue. In addition to studies discussed above, the NASA Ames Fatigue Countermeasures Program stands out as demonstrating some especially effective countermeasures. This program, which has been underway since 1980, has addressed strategic napping as a preventive strategy and an operational countermeasure to combat sleep loss, circadian disruption, and fatigue that occur as a result of multiple time zone changes, and extended, irregular duty schedules in flight operations.[18] The researchers found that there is scientific evidence showing that as a preventive strategy, napping before

---

[16] Itoi, A.; Cilveti, R.; Voth, M.; and others. 1993. Can drivers avoid falling asleep at the wheel? Relationship between awareness of sleepiness and ability to predict sleep onset. Washington, DC: AAA Foundation for Traffic Safety (p. 25). 33 p.

[17] Mitler, M.; Carskadon, M.A.; Czeisler, C.A.; and others. 1988. Catastrophes, sleep and public policy: consensus report. Sleep. 11(1): 100-109.

[18] Rosekind, Mark R.; Graeber, R. Curtis; Dinges, David F.; and others. 1993. Crew factors in flight operations. IX: Effects of planned cockpit rest on crew performance and alertness in long-haul flight operations. NASA Technical Memorandum 108839. DOT/FAA/92/24. Washington, DC.

fatigue develops is quite effective in an operational setting. A single nap of about 45 minutes in duration prior to a night without sleep can prevent significant loss of performance capability and fatigue throughout the night. The Safety Board agrees that the use of naps as a means to prevent fatigue prior to its onset is a worthwhile countermeasure. The Board cautions, however, that these naps should be a supplement to, not a replacement for, one continuous 8-hour sleep period.

Therefore, the Safety Board believes that the Federal Highway Administration, the Professional Truck Driver Institute of America, the American Trucking Associations, Inc., and the Commercial Vehicle Safety Alliance, and the National Private Truck Council in consultation with the U.S. Department of Transportation Human Factors Coordinating Committee should cooperatively develop and disseminate a training and education module that includes information about the need for an adequate amount of quality sleep, strategies for avoiding sleep loss such as strategic napping, consideration of the behavioral and physiological consequences of sleepiness, and an awareness that sleep can occur suddenly and without warning to all drivers regardless of their age or experience. Because of the strides that have been made in this area in the other transportation modes, particularly in aviation by NASA Ames, the Board urges the FHWA to consult the other modal administrations before developing this training and education module.

Another measure that was relatively highly correlated with fatigue was split sleep patterns. Split sleep patterns also ranked fifth in importance in discriminating between long-haul and short-haul operations. The HOS regulations contain an exemption that allows drivers using Department of Transportation-approved sleeper berth equipment to accumulate the required 8 consecutive hours off duty resting in a sleeper berth in two separate periods totaling 8 hours (neither period to be less than 2 hours).

The findings of this study show that truckdrivers with split sleep patterns were obtaining about 8 hours of sleep in a 24-hour time period; however, they obtained it in segments, on average of 4 hours at a time. Research, not available at the time the regulations were drafted by the Interstate Commerce Commission, has shown that sleep accumulated in short time blocks is less refreshing than sleep accumulated in one long time period.[19] Other research indicates that "...the more sleep is disturbed or reduced, for whatever reason, the more likely an individual will inadvertently slip into sleep."[20] A review of police accident reports has also demonstrated that decrements in performance occur earlier for drivers using sleeper berths (or drivers

---

[19] Dinges, D.F. 1989. The nature of sleepiness: causes, contexts, and consequences. In: Stunkard, A.J.; Baum, A. Perspectives in behavioral medicine: eating, sleeping, and sex. Hillsdale, NJ: Lawrence Erblaum Associates: 147-179. Chapter 9 (p. 147).

[20] (a) Mitler and others (1988, p. 107). (b) Rosekind, M.R.; Gander, P.H.; Connell, L.J.; Co, E.L. 1994. Crew factors in flight operations X: alertness management in flight operations. NASA/FAA Technical Memorandum DOT/FAA/RD-93/18.

with split sleep patterns) than for other drivers. The same research determined that split-shift, sleeper berth use (that is, driving without an 8-hour consecutive rest period) increased the risk of fatality more than two-fold. Sleep duration has been found to be as important to the recovery of performance abilities as is the quality of sleep experience.[21] Of the drivers for whom information on duty hours was available, 19 of 26 drivers with split sleep patterns (73 percent) had slept in a sleeper berth.

In drafting its original regulations, the Interstate Commerce Commission (ICC) noted the lack of scientific evidence about the nature of fatigue. The ICC was clearly frustrated at being unable to base its regulations on an empirical understanding of driver fatigue. Given what is now known about the inferior nature of split sleep patterns, it is unclear that the ICC would have permitted sleeper berth drivers to divide their required 8-hour off-duty period into two segments. Although the Safety Board encourages the use of sleeper berths for strategic napping and recognizes that sleeper berths may allow for continuous sleep, truckdrivers should not be encouraged or permitted to split their sleep. The current hours-of-service regulations do not permit drivers who sleep at a residence or in a motel to split their sleep periods. This exemption applies only to drivers who use sleeper berths. The Safety Board understands that in 1937, when these regulations were written, economic considerations required that freight move continuously—to keep produce and dairy products from spoiling, for example. However, the advent of refrigerated trucks eliminated concerns about food spoilage. The Board is also aware that the trucking industry wanted the flexibility provided by having drivers rest in their sleeper berths while waiting for other tasks to be completed (such as loading of tanks with crude oil). This would enable drivers to begin driving as soon as the tasks were completed and to drive for at least the time that they spent resting in their berths.

Although the Board is aware of the importance of just-in-time deliveries to the economic well-being of the manufacturing industry, the Board does not believe that this flexibility should be permitted at the expense of safety. The Safety Board is not aware of any physiological or laboratory research regarding the effect of split sleep patterns on performance; however, the Board's analysis has shown that the length of the most recent sleep period is the most important factor in determining fatigue and that the continuous nature of that sleep also is very important. Consequently, the Safety Board is asking the Federal Highway Administration to complete rulemaking within 2 years to eliminate 49 CFR 395.1 paragraph (h), which allows drivers with sleeper berth equipment to cumulate the 8 hours of off-duty time in two separate periods.

---

[21] Hertz, R.P. 1988. Tractor-trailer driver fatality: the role of nonconsecutive rest in a sleeper berth. Accident Analysis and Prevention. 20(6): 431-439.

Therefore, as a result of this study, the National Transportation Safety Board recommends that the National Private Truck Council:

> In cooperation with the Federal Highway Administration, the Commercial Vehicle Safety Alliance, the American Trucking Associations Inc., and the Professional Truck Driver Institute of America, develop and disseminate, in consultation with the U.S. Department of Transportation Human Factors Coordinating Committee, a training and education module to inform truckdrivers of the hazards of driving while fatigued. It should include information about the need for an adequate amount of quality sleep, strategies for avoiding sleep loss such as strategic napping, consideration of the behavioral and physiological consequences of sleepiness, and an awareness that sleep can occur suddenly and without warning to all drivers regardless of their age or experience. (Class II, Priority Action) (H-95-5)

Also as a result of the study, the Safety Board issued safety recommendations to the Federal Highway Administration, the Commercial Vehicle Safety Alliance, the American Trucking Associations Inc., the Professional Truck Driver Institute of American, the Independent Truck Owner Operators, the Owner-Operator Independent Driver's Association, the International Brotherhood of Teamsters, and the National Industrial Transportation League.

The National Transportation Safety Board is an independent Federal agency with the statutory responsibility "...to promote transportation safety by conducting independent accident investigations and by formulating safety improvement recommendations" (Public Law 93-633). The Safety Board is vitally interested in any actions taken as a result of its safety recommendations and would appreciate a response from you regarding action taken or contemplated with respect to the recommendation in this letter. Please refer to Safety Recommendation H-95-5 in your reply.

Chairman HALL and Members HAMMERSCHMIDT and FRANCIS concurred in this recommendation.

By: Jim Hall
Chairman