Assessment of Drowsy-Related Critical Incidents and the 2004 Revised Hours-of-Service Regulations

Rebecca L. Olson

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Richard J. Hanowski, Ph. D., Co-Chair
Tonya L. Smith-Jackson, Ph. D., Co-Chair
Brian M. Kleiner, Ph. D.

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ABSTRACT

In 2004, 5,190 people were killed due to a traffic accident involving a commercial motor vehicle (CMV), up from 4,793 people killed in 2001 (Traffic Safety Facts, 2004; Traffic Safety Facts, 2001). Driver drowsiness is an important issue to consider when discussing CMVs. According to the FMCSA, over 750 people are killed and 20,000 people are injured each year due to drowsy CMV drivers (as cited in Advocates for Highway and Auto Safety, 2001). Driver drowsiness is an important issue for CMV drivers for several reasons, including long work shifts, irregular schedules and driving long hours on interstates and highways with no scenic interruptions to help keep the driver alert. Because of these and other factors, including the high mileage exposure that CMV drivers face, drowsiness is an important issue in a CMV driver's occupation.

There were two main goals to this research: 1) gain a better understanding of the time-related occurrences of drowsy-related critical incidents (i.e., crashes, near-crashes and crash-relevant conflicts), and 2) obtain drivers' opinions of the 2004 Revised Hours-of-Service regulations. To do this, recent data were used from a Field Operational Test conducted by the Virginia Tech Transportation Institute in which 103 participants drove in an instrumented heavy vehicle for up to 16 weeks; video data, and sensor data were collected from each participant. In addition, actigraph data was collected from 96 of the 103 participants. Each vehicle was instrumented with four video cameras to capture images of the drivers face, the forward roadway, and the adjacent lanes on each side of the truck. In addition, multiple sensors were installed in the vehicle in order to collect data such as the driver's speed, braking patterns and steering wheel movement. These data were combined to provide a complete picture of each driver's environment and behavior while they drove their normal routes. Data analysts reviewed the data for

critical incidents (crashes, near-crashes, and crash-relevant conflicts) and determined a drowsiness level for each incident; these downiness levels were compared to drowsiness levels of baseline incidents (i.e., normal driving periods). The results show that drivers were more likely to have a drowsy-related critical incident between 2:00 pm and 2:59 pm. In addition to the video and sensor data, each driver was asked to fill out a subjective questionnaire regarding the revised HOS regulations. Drivers preferred the revised HOS regulations over the old HOS regulations and the number one item that was preferred in the revised HOS regulations is the 34-hour restart which allows drivers to restart their work week by taking off 34 consecutive hours.

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CHAPTER 1: INTRODUCTION

Defining the Problem

Vehicle safety is a major concern of the U.S. Department of Transportation (US DOT). Commercial motor vehicles (CMVs) are of particular interest for the National Highway Traffic Safety Administration (NHTSA) heavy-vehicle program and the Federal Motor Carrier Safety Administration (FMCSA). The Virginia Department of Motor Vehicles (DMV) defines a CMV as having the following characteristics:

- A single vehicle with a gross vehicle weight rating (GVWR) of 26,001 pounds or more.
- A combination of vehicles with a gross combination weight rating of 26,001 pounds or more if the vehicle(s) being towed has a GVWR of more than 10,000 pounds.
- A Vehicle that carries 16 or more passengers, including the driver.
- Any size vehicle that transports hazardous materials and that requires federal placarding (Virginia Department of Motor Vehicles, 2004).

Within the category of commercial motor vehicles are "large trucks," which are defined as vehicles weighing over 10,000 pounds GVWR. Large trucks may be further divided as single-unit trucks (e.g., delivery/panel vans) and combination trucks (e.g., tractor-trailers).

In 2004, 5,190 people were killed due to a traffic accident involving a large truck, up from 4,793 people killed in 2001 (Traffic Safety Facts, 2004; Traffic Safety Facts, 2001). Of these crashes, 77% of the people killed were in other vehicles, while 15% of the victims were drivers of large trucks (8% were non-occupants such as pedestrians) (Traffic Safety Facts, 2004). Statistics show that in 2004, one in every eight traffic fatalities was the outcome of a crash involving a large truck (Traffic Safety Facts, 2004) and one in every four traffic fatalities, among light-vehicle occupants, was the outcome of a multivehicle crash that involved a large truck (Advocates for Highway and Auto Safety, 2001). These statistics show the impact that drivers of large trucks have on all drivers on the road and not just on themselves. Therefore, increasing CMV and large truck safety will help to make the roadways safer for all drivers.

When discussing CMVs, one important aspect to consider is driver drowsiness. According to the FMCSA, over 750 people are killed and 20,000 people are injured each year due to drowsy CMV drivers (as cited in Advocates for Highway and Auto Safety, 2001). Driver drowsiness is an important issue for CMV drivers for several reasons. First, CMV drivers work long shifts (i.e., up to 11 hours driving/14 hours total) with no mandatory break time. Some CMV drivers also keep irregular schedules, getting up very early in the morning and sometimes driving through the night, a time when the human body naturally wants to sleep. In addition, CMV drivers often drive long hours on interstates and highways that provide little or no scenic interruptions to help keep the driver alert. Because of these and other factors, including the high mileage exposure that CMV drivers face, drowsiness is an important issue in a CMV driver's occupation.

In an effort to control driving time and reduce driver drowsiness, the Interstate Commerce Commission (ICC) adopted the first hours-of-service (HOS) regulations in 1938 that were to be followed by all CMV drivers. One purpose of the HOS regulations was to keep the roads safer by regulating the amount of time a driver can spend on the road during one shift. This is of concern because research has indicated that extended periods of driving lead to increased fatigue and drowsiness (Chatterjee et al., 1994; Mitler, Miller, Lipsitz, Walsh and Wylie, 1997; Williamson, Feyer and Friswell, 1996).

Project Overview

The purpose of this research is to study tractor-trailer drivers to gain a better understanding of driver drowsiness by examining time-related occurrences of drowsy-related critical incidents (i.e., crashes, near-crashes and crash-relevant conflicts), along with obtaining drivers' opinions of the 2004 Revised HOS regulations in an effort to suggest future recommendations to improve safety and compliance.

The data were collected in a Field Operational Test (FOT) designed to test a Drowsy Driver Warning System (DDWS) and was sponsored by the National Highway Traffic Safety Administration (NHTSA)/Federal Motor Carrier Safety Administration (FMCSA)/Federal Highway Administration ITS Joint Program Office (FHWA ITS JPO). The data were collected in a naturalistic setting and were used to conduct an analysis on drowsy-related critical incidents. Although the current analysis was not the main goal of the FOT, the large amount of continuous data that was collected provided many opportunities for additional analyses. The results from the DDWS FOT can be found in Hanowski et al. (2005).

CHAPTER 2: REVIEW OF THE LITERATURE

Human Factor's Issues in the Commercial Motor Vehicle Industry

Knipling (2001) outlines several human factors issues relating to CMV safety. Knipling states that the human component, when compared to environmental factors, is a major contributing factor in the cause of crashes. Chatterjee et al. (1994) and Beilock (1995) agree, stating that a significant cause of accidents involving CMVs is driver failure. Human behavior becomes an issue when drivers make poor decisions, unintentional errors, or are impaired (e.g., alcohol, fatigue) in some form (Knipling, 2001).

Driver fatigue and driver drowsiness has been a prominent issue in human factors research in past years. Due to aspects of a CMV driver's occupation such as driving long hours, nighttime driving, and irregular shift hours (Knipling, 2001), driver fatigue and driver drowsiness may impact a CMV driver's safety. A study conducted by the National Transportation Safety Board (NTSB) found that fatigue was the probable cause of 31% of fatal-to-the-driver accidents that were researched (NTSB, 1990). Researchers (Chatterjee et al., 1994; Mitler, et al., 1997; Williamson et al., 1996) believe the longer a driver is on the road, the drowsier he/she will become and the less alert he/she will be to react properly to potential conflicts. Fatigue and drowsiness are often used interchangeably; however, the two have separate meanings. Definitions of each are provided below.

<u>What is Fatigue?</u>

Fatigue "is a state of reduced physical or mental alertness which impairs performance" (Williamson et al., 1996; p.709). Dinges (1995) states that fatigue is "a neurobiological process directly related to the circadian pacemaker in the brain and to the biological sleep need of the individual" (p.42) and can not be "prevented by any known characteristics of personality, intelligence, education, training, skill, compensation, motivation, physical size, strength, attractiveness or professionalism" (p.42). There are physical aspects to a CMV driver's occupation that may lead to fatigue (e.g., loading or unloading of the truck). O'Neill, Krueger, Van Hemel, and McGowan (1999) found that "driver performance deteriorated more rapidly after the afternoon physical activity, suggesting that cumulative physical/general fatigue and time-of-day effects are sufficient to overpower some short-term effects of a change in activity" (FHWA, March, 1999; p.3). Over the years, fatigue has been difficult for researchers to study because it is hard to quantify and precisely measure. Although fatigue is an issue for drivers, a more important issue may be drowsiness.

What is Drowsiness?

Since the terms fatigue and drowsiness are often used interchangeably, there has been some debate on the topic. Drowsiness, which may also be referred to as "sleepiness", is the "inclination to sleep" (Stutts, Wilkins and Vaughn, 1999; p.7). It is possible for a person to be fatigued without being drowsy. Fatigue is the result of physical or mental exertion, while drowsiness may result from boredom, laziness, lack of sleep, hunger, or many other factors. Therefore, fatigue and drowsiness are not the same thing. The DDWS FOT, from which this research is based, was directed at drowsiness.

An important aspect to understand about drowsiness is that it occurs naturally in every person. Each person's body functions on a 24-hour circadian rhythm, based on whether it is light or dark outside (along with other measures such as body temperature, melatonin levels, etc.). This causes two drowsy lows during a 24-hour period: one during the middle of the night (between approximately 12:00 am and 6:00 am), and the other occurs between 2:00 pm and 4:00 pm (Stutts et al., 1999). Because of this, drowsiness is something that our body is not able to fight. Williamson et al. (1996) and Dingus et al. (2002) found that fatigue increases during the hours of 12:00 am (midnight) to 6:00 am.

Figure 1 shows a graph of an alertness circadian rhythm over a 24-hour time period. It can be seen that the low points occur between 1:00 pm and 3:00 pm and again from about 12:00 am (midnight) to 6:00 am.

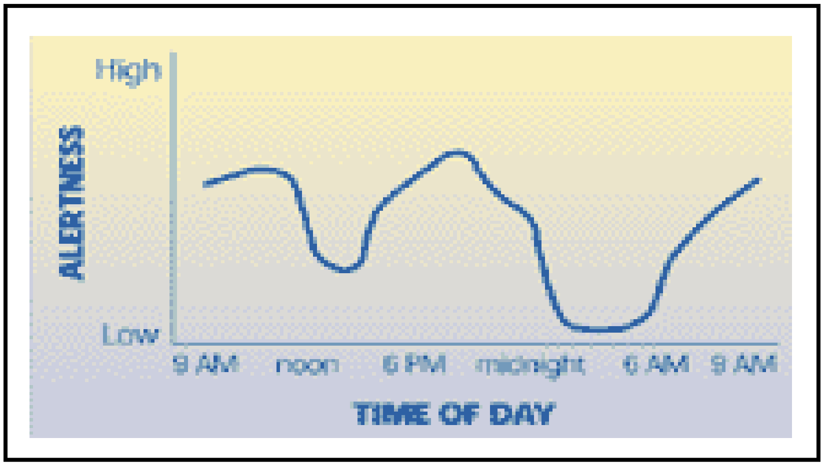

Figure 1. A graph showing an alertness circadian rhythm.

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What Causes Drowsiness in CMV Drivers?

Several studies (McCartt et al., 2003; Stutts et al., 2003; Philip et al., 2002; Williamson et al., 1996; and Pack et al., 1995) have investigated factors that lead to drowsy driving. Each of these studies is described in more detail below.

Philip et al. (2002) studied sleep patterns of European commercial vehicle drivers. The study was comprised of 227 truck drivers (98.7% men) who completed several questionnaires at a truck stop. The study was conducted by female interviewers who spent four consecutive days (Monday through Thursday) at a truck stop, between the hours of 8:00 am and 10:00 pm, and asked for volunteer drivers to take one hour to fill out the following four questionnaires, 1) Basic Nordic Sleep questionnaire, 2) Epworth Sleepiness Scale, 3) Standard Shift Work questionnaire and, 4) a detailed sleep log covering sleep duration for the previous two days of their work week.

Philip et al. first investigated total nocturnal sleep time during a typical week for drivers (drivers usually work Monday through Friday). They found that on the first day home (at the end of the work week – usually Friday night) drivers had an average bedtime delay of

67 minutes as compared to the previous night. On the second night home (usually Saturday night) after the driver had an entire day off of work, there was an average delay of 31 minutes compared to the onset of sleep the night before (usually Friday night). They also found that during the first two nights at home (usually Friday and Saturday night) there was an increase in total sleep per night, but on the last night home, prior to a new work week (usually Sunday night), there was an earlier wake-up time and an average of 181 minutes less of sleep than the previous night (usually Saturday night). This finding may help to explain why other research (Dingus et al., 2000) has found that the most critical incidents occur during the first days of a driver's shift for a given work week.

Philip et al. also recorded the average sleep time in the 24-hour period prior to the interview. When the sleep time in the 24-hour period prior to the interview was compared to the sleep time during a "complete rest period" (usually Saturday night), 36.7% of drivers had at least a 2-hour shorter sleep period, 11.9% had at least a 4-hour shorter sleep period and 2.2% of drivers at least a 6-hour shorter sleep period. Philip et al. refers to the amount of sleep that the drivers lost (as compared to a "complete rest period") as "sleep debt".

From these findings, Philip et al. suggests that driver education be improved along with driving regulations. For instance, they suggest that regulators take into consideration "(1) the distance between home and the starting locations of the journey, and (2) the impact of the start time of the journey on circadian shifts" (p.510).

A second study by McCartt et al. (2000) surveyed a representative sample of professional truck drivers traveling on New York Interstates. A total of 593 drivers were interviewed; 32.4% were interviewed at public rest areas, 39.3% were interviewed at private truck stops, and 28.3% were interviewed at truck inspections at public rest areas. Drivers could participate as long as they had been driving a tractor-trailer for at least six months, made at least occasional trips of two or more days, and drove a minimum of 50,000 miles/year for work; drivers were given $5 food vouchers for their participation. The questionnaire consisted of 64 questions and took 15 – 20 minutes for drivers to complete. The questionnaire was developed by the FHWA's Office of Motor Carriers, state agencies involved in New York's Motor Carrier Safety Assistance Program, and the New York State Motor Truck Association. The study's author's primary interest in the study was to obtain the driver's self report of having fallen asleep at the wheel. From this, a factor analysis was done to obtain a set of prediction factors.

Results from the study showed that 47.1% of the drivers reported having fallen asleep at the wheel (ever) while 25.4% reported having fallen asleep at the wheel in the past year. The factor analysis resulted in the following six factors as predicting the likelihood of a driver falling asleep behind the wheel, 1) arduous work schedule, 2) poor sleep on road, 3) daytime sleepiness, 4) symptoms of sleep disorder, 5) night-time drowsy driving, and 6) older, long-time driver. The study did not provide specific countermeasures for preventing these six factors but did suggest that drivers who drive primarily at night and who get their longest period of sleep during the day are more likely to be drowsy while driving. To reduce this problem, McCartt et al. suggest trying to identify drivers who often have their longest period of sleep during the day and those with sleep-related disorders such as sleep apnea.

Williamson et al. (1996) conducted a study using 27 CMV drivers who routinely drove on one of the major highways in Australia connecting the cities of Sydney and Melbourne. Professional truck drivers in Australia have three different driving regimes - staged trips (where two drivers leave from two different locations, meet at a third location to switch trucks and load, and return to their original location), two-up regime (where two different drivers share the driving time for a trip) and single driver regime (where a single driver drives for the entire trip). Drivers who participated in this study were asked to make three different trips, one under each regime. Although this study was specifically interested in fatigue in staged trips, some of the results can be generalized to the trucking industry as a whole.

Fatigue was measured several ways throughout the study including, heart rate, truck speed, and steering variability. Drivers were also tested on several information-processing skills at three different times during their trip - beginning, middle and end (with the exception of flexible trips, those drivers were not tested during the middle of the trip so as not to interrupt their freedom to plan breaks). The information processing skills tested were perceptual sensitivity, simple manual reaction time, the capacity for sustained attention on a monotonous task, and the ability to respond to an unpredictable stimulus; practice trials were given before each test was recorded. Finally, drivers were asked to rate their fatigue levels at the beginning and end of each trip, and each break, using the seven-point Stanford Sleepiness scale, in addition to filling out questionnaires pertaining to the work and sleep activities for the week prior to the study.

From a combination of the above measures, this study found that fatigue increased over the length of the trip, particularly between the start of the trip and the first break for all three regimes. In addition, the study found that the pre-trip level of fatigue was an important factor for determining fatigue later in the trip.

There are also several studies on light vehicles that found relevant results pertaining to drowsiness. Stutts et al. (2003) conducted a study on North Carolina light vehicle drivers who were either considered "asleep" or "fatigued" at the time of a crash (as assessed by police reports). The authors were interested in determining driver risk factors for sleep-related crashes, whether short-term sleep loss was a risk factor for sleep-related crashes and whether driving exposure was associated with sleep-related crashes. Drivers who were not considered either asleep or fatigued, but were still involved in a crash, were used as a control group; a total of 312 asleep drivers, 155 fatigued drivers and 529 control drivers participated; drivers had to be 18 or older to participate. The above driver information was obtained from police reports on file in North Carolina. A second control group was used consisting of drivers, aged 18 or older, who were not involved in any type of crash but had renewed their drivers license in the past six months; there were 407 participants in this control group. Participants name and information were obtained from a North Carolina Department of Motor Vehicles (DMV). Participants were first contacted by mail with a letter explaining the study and requesting their cooperation when they were contacted later by telephone. Drivers were contacted by one of five trained interviewers (who were blind as to what group the participant belonged in) and were asked a set of questions that lasted approximately eight to ten minutes.

Stutts et al. found that the asleep and fatigued participants were significantly younger (average age of 35.7 years for both groups) than either the control (average age of 39.4 years) or non-crash (average age of 57.5 years) participants; in addition, over 70% of the asleep and fatigued participants were male while 55% of the control group and 48% of the non-crash group were male.

There were several work factors found to be associated with sleep-related crashes including working two or more jobs, working a night shift or "other" (i.e., rotating shifts and working long hours for extended periods of time) work schedule, and working 60 or more hours/week. In addition, the authors found that the average number of hours slept/night was strongly associated with being in a sleep-related crash. Also, Stutts et al. found that drivers who were in a sleep-related crash were more likely to report that they usually had trouble falling asleep or staying asleep, usually had a poor quality of sleep each night, and usually had higher levels of daytime sleepiness. Next, drivers involved in sleep-related crashes were more likely to report driving 20,000 or more miles/year, driving two or more hours/day and driving in the dark or driving between the hours of 12:00 am and 6:00 am, when compared to drivers who were not involved in a crash. Finally, almost 25% of drivers in a sleep-related crash reported driving drowsy more than 10 times in the past year. These results are similar to those found in CMV studies, indicating that drowsiness affects all drivers similarly.

Pack et al. (1995) also investigated light-vehicle crashes that took place in North Carolina. These crashes occurred between 1990 and 1992, in which the driver was considered asleep at the time of the crash. These fall-asleep crashes were retrieved from the North Carolina database of crashes as determined by crash reports filled out by an officer at the time of the crash. There were 5,104 fall-asleep crashes during the two-year period, and for 771 of the crashes the driver was also considered intoxicated; these crashes were removed from the total leaving 4,333 crashes that were used in the study. When fall-asleep crashes (0.46%) were compared to crashes in which the driver was intoxicated (2.99%) and all other crashes (96.55%), the authors found that fall-asleep crashes were primarily single-vehicle crashes (77.5%) in which the driver drove off the side of the road on either the right or left side (78.5%). In addition, fall-asleep crashes most often occurred at speeds higher than 50 mph (62.4%) and 55% of the fall-asleep crashes were caused by drivers under the age of 25. Finally, fall-asleep crashes, as well as intoxicated crashes and other crashes, were primarily caused by male drivers (74.5% for fall-asleep crashes).

Pack et al. (1995) also found that across all fall-asleep crashes, they occurred most often during the night hours (increasing in frequency from 11:00 pm to 8:00 am) and during the afternoon hours (3:00 pm to 6:00 pm). This result is similar to that of past research (Dingus et al., 2002 and Wylie et al., 1996). Age was also a factor for the time of day in which the fall-asleep crash occurred; for fall-asleep crashes that were caused by drivers between the age of 16 and 45, there were an increased amount of crashes during the night hours while drivers aged 46 to 65 had a decreased amount of crashes during the night hours. When fall-asleep crashes were compared to intoxicated crashes, the intoxicated crashes increased in frequency between 12:00 pm and 12:00 am (with no mid-afternoon spike) and decreased in frequency after 3:00 am. This helps to show that fall-asleep crashes follow the same pattern as the body's circadian rhythm.

Although the above two studies (Stutts et al., 2003 and Pack et al., 1995) investigated light vehicle drivers, as opposed to commercial vehicle drivers, the results are similar to those of studies looking at commercial vehicle drivers (McCartt et al., 2003), showing that drowsiness occurs in all aspects of driving and is an important issue to study.

Task demands.

In addition to the factors listed above, drivers are also subject to task demands over which they have little or no control. CMV drivers are part of a larger network that includes shippers, dispatchers, and motor carriers. Often, time pressures from dispatchers lead CMV drivers to violate speed limits and HOS regulations, which may lead to increased fatigue (Chatterjee et al., 1994). Beilock (1995) found that the number of hours driven by a CMV driver often exceeds HOS regulations. Beilock conducted a survey in Florida and found that 26% of drivers admit to violating the HOS regulations. One reason for these violations is the ease with which drivers can falsify their logbooks. CMV drivers often refer to their log books as “joke books” or “comic books,” meaning that drivers do not take them seriously (Chatterjee et al., 1994).

Dispatchers often pressure CMV drivers due to tight schedules set by shippers (Beilock, 1995; Braver et al., 1999; Chatterjee et al., 1994). Approximately 20% of CMV drivers reported penalties for late deliveries. Such penalties may include loss of bonuses, fines, job loss, suspension, demotion, and reprimands. Penalties were more likely to be reported from drivers who work for large companies (i.e., 50 or more trucks) (Braver et al., 1999).

Interestingly, when dispatchers were asked a similar question about penalties, 60% said that penalties were never given out, while 40% said penalties were rarely given out. In addition, dispatchers were asked what percentage of their shippers gave “more than enough time” for deliveries versus “not enough time” for deliveries, and over one-third of the dispatchers reported that 95% of the shippers gave “more than enough time” (Braver et al., 1999). This may show that dispatchers seem to believe CMV drivers have adequate time to deliver the goods properly.

Risk perception.

Although many things have been identified as increasing a driver’s risk for having a drowsy-related critical incident, one problem identified in the drowsiness research is that drivers often underestimate their levels of fatigue (Wierwille et al., 2003). An Australian study (Arnold et al., 1997) found similar results concerning drivers’ perceptions of fatigue. When drivers and companies were asked about their own levels of fatigue, only 10% of drivers reported that fatigue was often a problem, while only 1% of company representatives reported that fatigue was often a problem (for their drivers). Interestingly, when drivers and companies were asked about their perceptions of other drivers' level of fatigue, 39% of drivers reported that fatigue was often a problem in other drivers, while 42% of company representatives reported that fatigue was often a problem for other drivers.

This may show that drivers understand the level at which fatigue is a problem for truck drivers; however, drivers do not perceive themselves to be a threat to others on the road due to fatigue. Therefore, their risk perception is low, which likely will not lead them to participate in fatigue countermeasure activities.

Drowsiness and Driver Performance

Although this research is devoted primarily to drowsiness, and not fatigue, Dinges (1995) states that he uses the terms fatigue and sleepiness (or drowsiness) interchangeably, to describe the "neurobiological processes regulating circadian rhythms and the drive to sleep" (p.4); therefore, the following section is considered relevant. Fatigue in CMV drivers has been known to decrease driver performance in such areas as reaction time and vigilance. A study by Dinges (1995) found that fast physical reaction time decreased by 5% to 25% due to fatigue. This could prove detrimental to a heavy-vehicle driver. If a driver is drowsy and a conflict arises that requires an evasive maneuver on the part of the driver, his/her reaction time to press the brake, or make a quick steering maneuver, may be impaired. Delayed reaction time could lead to a vehicle crash. Dinges also found that fatigue may lead to an increase in errors while operating a vehicle. Dinges states that fatigue "increases errors (of omission and commission) and the compensatory effort needed to avoid them, while at the same time it can lead to a decrease in the concern about making errors" (p.44).

Vigilance may also decrease in the presence of fatigue (Dinges, 1995). A driver who is not drowsy and a driver who is drowsy may begin a vigilance task (i.e., the start of their trip) at the same time with the same attention level; however, the driver who is drowsy will show a decrease in vigilance considerably sooner than the other driver. This again may lead to a lack of attention and the ability to perceive conflict situations.

Wylie et al. (1996) found that steering wheel variability and lane tracking variability were greater for drowsy events than for non-drowsy events. Chatterjee et al. (1994) states that fatigue decreases alertness, which leads drivers to drive off of the road. Currently, there is little empirical data directly linking driver drowsiness and driver performance (e.g., lane deviation), but this is something VTTI plans to investigate in the future.

Hours of Service

A Need for Revised Hours

In 2000, the National Sleep Foundation (NSF) called for new HOS regulations. At that time, the current HOS regulations had been in effect since 1938, with the last revision occurring in 1962. It was proposed that the new regulations be based on scientific research concerning sleep. One major push for revised regulations was to base the regulations on a 24-hour schedule, which is more consistent with the natural circadian rhythm. This would allow truck drivers to follow a more natural sleep schedule and to obtain a better quality of sleep each night. For example, under the old regulations, the drivers were allowed to drive for ten hours and had to take an eight hour break. If a driver started a shift at 8:00 am, his/her schedule might look like that shown in Table 1. It can be seen from this schedule that the driver would have to sleep between 6:00 pm and 2:00 am, when the circadian rhythm reaches one of the highest points of alertness (9:00 pm) (Stutts et al., 1999). He/she would begin driving again from 2:00 am to 12:00 pm, when the circadian rhythm reaches one of the lowest levels of alertness (2:00 am to 4:00 am) (Stutts et al., 1999). Therefore, the schedule of this driver would work against the body's natural clock and would cause the driver to drive during a period of time with the lowest level of alertness.

Table 1. Hypothetical schedule of a CMV driver based on the old HOS.

On-Duty Driving Time	Off-Duty Time
8:00am – 6:00pm	6:00pm – 2:00am
2:00am – 12:00pm	12:00pm – 8:00pm

Under the old HOS regulations, recent studies have found that drivers only receive between 4.8 hours (Wylie et al., 1996) to 5.18 hours (Mitler et al., 1997) of sleep per night, which is approximately three hours less than is required to feel well rested (FHWA, March, 1999). These, along with other considerations, were the catalyst for revising the HOS regulations. Table 2 is a summary of the old HOS regulations and the revised HOS regulations. Each is described in detail.

Table 2. Summary of the old HOS regulations and the revised 2004 HOS regulations.

Old Hours-of-Service Regulations (1938 to January 3, 2004)	2004 Hours-of-Service Regulations (January 4, 2004 to September 30, 2005)
CMV driver may drive 10 hours after 8 hours off-duty.	CMV driver may drive 11 hours after 10 hours off-duty.
CMV driver may not drive after 15 hours on-duty, following 8 hours off-duty.	CMV driver may not drive beyond the 14th hour after coming on-duty, following 10 hours off-duty.
CMV driver may not drive after 60/70 hours on-duty in 7/8 consecutive days.	CMV driver may not drive after 60/70 hours on-duty in 7/8 consecutive days. ➢ A driver may restart a 7/8 consecutive day period after taking 34 or more consecutive hours off-duty.

Hours-of-Service (1938 – January, 2004)

Under the old HOS regulations, a driver was permitted to be on-duty for 15 hours, 10 of which could be driving time and after which the driver was mandated to take an 8 hour break. In an effort to change this regulation, it was argued that the 8 hour break was not long enough to provide the driver with enough time to get an adequate amount of sleep, eat their meals, bathe, take care of family business, and get themselves to and from work. In addition, the old regulations stated that drivers may not drive more than 60 hours in seven consecutive days, or 70 hours in eight consecutive days (FMCSA, 2003). The old HOS regulations were in effect from 1938 until January 3, 2004.

Hours-of-Service (January, 2004 – September 30, 2005)

After several years of collecting scientific data regarding sleep, the revised regulations were passed and put into effect on January 4, 2004. The initial proposal suggested categorizing the trucking industry into five separate categories, but there were too many complications regarding certain companies fitting into more than one category. To solve this problem, under the 2004 revised regulations all for-hire, private carriers and drivers operating a "property carrying" commercial vehicle in interstate commerce are forced to comply. The one exception is for intrastate commerce, which are trucking companies who only travel within their state lines. Intrastate drivers are subject to rules by their individual states and may be subject to the revised HOS regulations if their state chooses to adopt the 2004 revised regulations (FMCSA, 2003).

The revised HOS regulations are as follows:

- A driver is permitted to drive for 11 hours.
- A driver is mandated to take a 10 hour break.
- A driver is permitted to be on-duty for 14 hours (including both driving time and non-driving time such as loading/unloading, waiting, meals, and naps).
- A driver may not drive more than 60 hours in seven consecutive days, or 70 hours in eight consecutive days.
- A driver may restart a seven or eight day consecutive period after taking 34 consecutive hours off (FMCSA, 2003).

Hours-of-Service (October 1, 2005 – Present)

In July 2004, the Public Citizens brought a law suit against FMCSA stating that the revised HOS regulations were not supported by scientific research (United States Court of Appeals, 2004). Since then, FMCSA has sponsored (e.g., Hanowski et al., 2005) and gathered more research to support the revised HOS regulations. In August 2005, FMCSA released a new version of the revised HOS regulations with minor adjustments; these changes are listed in Table 3 below.

Table 3. Summary of the 2004 HOS regulations and the 2005 HOS regulations.

2004 Hours-of-Service Regulations (January 4, 2004 to September 30, 2005)	2005 Hours-of-Service Regulations (October 1, 2005 to Present)
CMV driver may drive 10 hours after 8 hours off-duty.	No change
CMV driver may not drive after 15 hours on-duty, following 8 hours off-duty.	No change
CMV driver may not drive after 60/70 hours on-duty in 7/8 consecutive days.	No change
CMV drivers using a sleeper berth must take 10 hours off duty, but may split sleeper-berth time into two periods provided neither is less than 2 hours.	CMV drivers using a sleeper berth must take at least 8 consecutive hours in the sleeper berth, plus 2 consecutive hours either in the sleeper berth, off duty, or any combination of the two.

For the purpose of this research, any reference to the revised HOS regulations will refer to the 2004 regulations that were in effect from January 4, 2004 until September 30, 2005; this research; the sleeper berth change made to the 2005 HOS regulations does not affect this research.

<u>How the Revised Hours-of-Service Regulations May Contribute to Drowsiness</u>

One concern of the revised HOS was that an increase in the number of hours that a driver is allowed to drive during a shift from 10 hours to 11 hours would result in increased drowsiness. The following study was sponsored by the FMCSA and was cited in the final ruling (FMCSA, 2005) for the revised HOS regulations.

VTTI recently conducted a study, using the same DDWS FOT data that was used for this research, to determine if drivers have a higher risk of having a drowsy-related critical incident in the eleventh hour when compared to the tenth hour of driving (Hanowski et al., 2005). Using the drive history software detailed in Chapter 3 of this research, VTTI was able to find all critical incidents that occurred in the tenth and eleventh hour of driving for all data ranging from May, 2004 to May 1, 2005; this dataset included 82 drivers. The data caveats listed under the "Driving History Software" section in Chapter 3 also hold true for this study. Only critical incidents that occurred in the tenth hour where the driver also drove into the eleventh hour were used. The data prior to the critical incident was also checked to ensure that there was not any missing data that would possibly change the driving time; any critical incidents that did have prior missing data were not included in the analysis. Table 4 shows the data used in the analyses; subject driver at-fault incidents were determined and verified through video review by three analysts.

Table 4. Data for two analyses conducted (Hanowski et al., 2005). Reprinted by permission.

Analysis 1 – All Incidents	Analysis 2 – Subject Driver at Fault
Total critical incidents in 10th Hour = 28	Total critical incidents in 10th Hour = 20
Crashes in 10th Hour = 0	Crashes in 10th Hour = 0
Near-Crashes in 10th Hour = 6	Near-Crashes in 10th Hour = 2
Crash-Relevant Conflicts in 10th Hour = 22	Crash-Relevant Conflicts in 10th Hour = 18
Total critical incidents in 11th Hour = 25	Total critical incidents in 11th Hour = 19
Crashes in 11th Hour = 2	Crashes in 11th Hour = 0
Near-Crashes in 11th Hour = 3	Near-Crashes in 11th Hour = 3
Crash-Relevant Conflicts in 11th Hour = 20	Crash-Relevant Conflicts in 11th Hour = 16

Since there were less critical incidents in the eleventh hour than the tenth hour for both groups considered, no analyses were needed to determine that there is not an increased risk of driving in the eleventh hour compared to the tenth hour. Since the data used for this analysis came from the DDWS FOT a second analysis was done to determine if the existence of the technology being tested had any influence on the critical incidents. To do this, only critical incidents that occurred during the control condition were used. There were 16 critical incidents that occurred in the tenth hour and 16 critical incidents that occurred in the eleventh hour of the control condition; because there was the same number of critical incidents, it can be concluded that there was no significant difference in the tenth hour when compared to the eleventh hour. Finally, only subject-driver-at-fault critical incidents, which occurred in the control condition, were used; there were 10 critical incidents that occurred during the tenth hour and 13 critical incidents that occurred during the eleventh hour. An odds ratio was calculated and found that there was not a statistical difference in the number of critical incidents between these two groups. These analyses found that drivers are not at an increased risk when driving one extra hour as allowed by the 2004 and 2005 HOS regulations.

Summary

The above literature shows that there are many risk factors associated with drowsy driving such as driver age, gender, quantity of sleep per night, and night driving. The large number of drivers who admit to falling asleep behind the wheel indicates how driver drowsiness is such an important issue to study in the trucking industry. There are aspects of the trucking industry that are out of the control of the driver such as schedules and time pressure from the company, which may lead drivers to drive for extended hours to ensure on-time deliveries and to prevent penalties for late deliveries. In addition, drivers are not often aware of how tired they are and may continue to drive for several hours under unsafe conditions (Wierwille et al., 2003).

The HOS regulations have been revised (in 2004 and 2005) to help reduce the levels of drowsiness and to help increase safety for commercial motor vehicles. It is believed that the extended hour of driving does not increase the driver's risk of having a critical incident (Hanowski et al., 2005) and it is hoped that the extended off-duty time will allow drivers to obtain extra sleep each night.

This research looks at time-related factors such as time of day, day of shift and driving time to see when critical incidents and drowsy-related critical incidents occur under the revised HOS regulations. While it was not possible to determine the effects of the revised HOS regulations from this research (since it was not possible to obtain information from the drivers while they were off-duty) it is believed that the subjective questionnaires will provide some useful information as to drivers' opinions of the revised HOS regulations.

CHAPTER 3: METHODS

Experimental Goal

The two-fold purpose of this research is to 1) gain a better understanding of the time-related factors associated with the occurrence of drowsy-related critical incidents (i.e., crashes, near-crashes and crash-relevant conflicts), and 2) obtain drivers' opinions of the revised HOS regulations in an effort to suggest future recommendations to improve safety and compliance.

Research Questions and Hypotheses

The research questions (RQ) and hypotheses (H) are as follows:

<u>Research Question 1: Time-related conditions for drowsy-related critical incidents</u>

RQ 1.1: During what time of day do the most drowsy-related critical incidents occur?
H 1.1: It is expected the data will show the most drowsy-related critical incidents occur during the night hours and during the early afternoon which is equivalent to the circadian rhythm lows (Stutts et al., 1999). Wylie et al. (1996) found time of day to be the strongest predictor of decreased driving performance when compared to other measures. Wylie et al. (1996) and Dingus et al. (2002) both found that drivers are more likely to have critical incidents during the night hours. In addition, Hanowski et al. (2000) found that Local Short/Haul drivers are most likely to have (driver-caused) critical incidents in the early afternoon.

RQ 1.2: During what day of a driver's shift (e.g., first, second, etc.) do the most drowsy-related critical incidents occur?
H 1.2: It is expected that the largest number of drowsy-related critical incidents will occur during the beginning of a drivers work week. Hanowski et al. (2000) and Dingus et al. (2002) found that drivers are likely to have more critical incidents on the first days of

their shift, which may be due to lack of sleep during time off. Hanowski et al. (2002) found that drowsy-related critical incidents occurred most often at the beginning of the week while non drowsy-related critical incidents occurred at a stable rate across most workdays. For both the fatigue and non-fatigue group, there were considerably fewer critical incidents on the fifth workday as compared to the first four days. Dingus et al. (2002) also found that critical incidents most often occurred early in the driver's work week, while the least number of critical incidents occurred on the last day of the driver's work week.

RQ 1.3: During what hour of driving (for a given shift) do the most drowsy-related critical incidents occur?

H 1.3: Time on task is not expected to have a large impact on drowsiness in this data. According to Dingus et al. (2000), the largest amount of critical incidents occurred during the first hours of a driver's shift while the least amount of critical incidents occurred during the last four hours of a driver's shift. Wylie et al. (1996) found that drivers gave a higher self-report of drowsiness as they spent more hours driving, but there was not a decrease in performance as driving time increased. Although one hypothesis that led to the Hours-of-Service regulations was that drowsiness increases as driving time increases (FMCSA, 2003), Wylie et al. (1996) has found that time of day is a much stronger predictor of drowsiness than time on task.

<u>Research Question 2: Sleep Quantity</u>

RQ 2: Are drivers getting more sleep under the 2004 revised HOS regulations?

H 2: It is expected that drivers will receive more sleep under the revised HOS regulations when compared to the old HOS regulations. The revised HOS regulations require drivers to take an additional two hours of off-duty time between each shift (10 hours vs. 8 hours; FMCSA, 2003). Since drivers have many things to take care of during off-duty time such as getting to and from work, eating, personal hygiene, errands, spending time with family and friends and sleeping, it is obvious that it is not possible to get the full six to eight hours of sleep that drivers have reported they need to feel well rested (FHWA, March, 1999) and to also do the other tasks listed.

In extending the amount of off-duty time, it is anticipated that drivers will be able to get more sleep under the revised HOS regulations. Wylie et al. (1996) found that drivers were only getting an average of 4.8 hours of sleep per night under the old HOS regulations. Over several days, lack of sleep can lead to sleep debt and have detrimental effects on the driver's ability to drive his/her commercial motor vehicle safely; furthermore, it make take several full nights of sleep (at least eight hours) to recover from sleep debt, which drivers may not be able to do if they work five to six days a week.

Research Question 3: Driver Opinions

RQ 3: What are drivers' opinions of the revised HOS regulations?

H 3: The revised HOS regulations allow drivers to drive one additional hour (11 hours vs. 10 hours; FMCSA, 2003) per shift and allow drivers to work (including driving time and non-driving time) a total of 14 hours a day. The 14-hour shift, along with the 10-hour mandatory off-duty time is an effort to require drivers to work on a more natural 24-hour cycle, thus reducing the fatigue-related effects of the circadian rhythm. In addition to a more natural work schedule, the revised HOS regulations allow drivers to work up to an extra five hours (in a typical five-day work week), thus allowing them to bring home extra money. Finally, as mentioned above, the extra two hours of off-duty time is an attempt to allow drivers to get extra sleep each night, hence reducing their levels of fatigue while working. It is hypothesized that the above changes will bring about a positive reaction from drivers and increase compliance with the HOS regulations.

Experimental Design

The following section describes, in detail, the experimental design used for the analysis. Each independent and dependent variable is listed along with the objective and subjective data that was collected during the study.

Independent Variables

There were three independent variables used in the analysis including - time of day, day of shift, and driving hour. Each variable is listed in more detail below.

Time of Day

As previously mentioned, time of day has been found to be a strong predictor of drowsy-related critical incidents (Wylie et al., 1996). Time of day is defined as the time that the critical incident occurred (e.g., 2:00 pm). Given that the data collection method provided continuous data and provided an image of the driver's face, it was possible to obtain critical incidents from all hours throughout a 24-hour period and to also asses the level of fatigue for each critical incident. This allowed for a comparison of drowsy-related critical incidents to see if drowsiness is more prominent at certain times throughout the day.

Day of Shift

Day of shift is the number of days (e.g., first, second, etc.) that the driver has been working since he/she last took a 34-hour or longer break. The 34-hour or longer break is based only on driving data, since the study did not collect data from the drivers while they were not in the truck (the procedure for determining day of shift, along with the remaining independent variables, is described below). Day of shift has also been found to be a predictor or critical incidents from past research (Dingus et al., 2002; Hanowski et al., 2000).

Driving Hour

Driving hour is measured as the amount of time that the driver has been driving (i.e., that the truck speed is > 0) since the beginning of his/her shift until the occurrence of a critical incident. As mentioned earlier, Dingus et al. (2002) found that critical incidents most often occur during the first hours of a drivers driving period.

Driving history software.

In order to obtain the values for the independent variables (driving hour, and day of shift) an addition was made to the data viewing/reduction software. Also created by VTTI, the data viewing/reduction software scanned each data file, for a given driver, in order by date. The software program began with the first file for a driver and created 'trips' from all of the data for that driver. A trip can also be thought of as a driver's work-day shift which began as soon as the driver moved his/her truck (speed > 0). The trip continued until there was a six hour or longer gap (truck speed = 0) in the data (the revised HOS requires a 10 hour break between shifts; the software program assumed that any lapse in driving for six hours or longer was a break). The trip time, or shift time, contains driving time plus non-driving time (i.e., breaks). The driving time was recorded for any time that the truck was in motion (speed > 0). If the truck stopped (speed = 0) for any amount of time less than 6 hours (and greater than 10 minutes) it was considered a break. If the truck stopped for less than 10 minutes it was ignored because it was unknown if the driver was actually taking or break or was stuck in traffic.

Time since last break is recorded as the amount of time since the truck speed was last 0; this value resets each time the truck speed is equal to 0. Trips continue to accumulate until the driver takes a break (i.e., truck speed equals 0) of 34 hours or longer; this value was determined by the 34-hour restart rule in the revised HOS regulations. Once a minimum 34-hour break has occurred, a new work week begins. Each trip in a work week is considered a new day of shift. Because of this software, it is possible to see how many hours the driver has been driving (driving hour), how many hours the driver has been working (shift hour), how many hours since the driver last took a break (time since last break) and how many days the driver has been working (day of shift) for any given point during the driver's data collection (i.e., a critical incident). Table 5 is an example of the information resulting from the drive history software.

Table 5. Example of drive history information.

Trip ID	Trip Begin Time	Trip Time	Drive Time	Break Time	Day of Shift
1	22:00	9:10	6:38	14:49	1
2	22:00	8:52	6:23	15:07	2
3	22:00	6:36	1:33	17:23	3
4	22:00	7:58	2:45	16:01	4
5	22:00	10:00	7:30	13:59	5
6	22:00	7:15	4:04	14:58	1
7	20:14	10:49	5:00	14:56	2
8	22:00	3:39	1:03	20:28	1

Dependent Variables

The dependent variables included drowsy-related critical incidents, quantity of sleep and post-study questionnaire data. Each is listed below in more detail.

Objective Measures

Drowsy-related critical incidents.

The data analysis included data collected in the naturalistic study, from May 2004 until May 31, 2005. This included video and performance data for 95 of the 103 drivers, totaling approximately 2.5 million miles of driving. These data were used to identify critical incidents (crashes, near-crashes and crash-relevant conflicts) each of which is defined below. The definitions are listed in descending order by level of severity.

The definitions listed below are adapted from the recently completed 100-Car study (Dingus et al., 2005) in which 100 light vehicles were instrumented in Washington D.C. One addition to the 100-Car definitions is the ‘Crash: Tire Strike’ category. This was added to describe incidents in which the driver made contact with another object and one of the tires of the instrumented vehicle; most of the incidents involve the driver running over a curb in a tight intersection. Although the incidents technically fit into the ‘Crash’ category, it did not seem appropriate to group an incident where the driver simply ran over a curb in the same category with an incident where the driver rolled his truck over; therefore, a new category was created.

> Crash. Any contact with an object, either moving or fixed, at any speed in which kinetic energy is measurably transferred or dissipated. Includes other vehicles, roadside barriers, objects on or off of the roadway, pedestrians, cyclists or animals. (Note: this category does not include minimal contact as described in the 'Crash: Tire Strike' category.)

> Crash: Tire Strike. Any contact with an object, either moving or fixed, at any speed in which kinetic energy is measurably transferred or dissipated where the contact occurs on the truck's tire only. No damage occurs during these events.

> Near-Crash. Any circumstance requiring a rapid, evasive maneuver by the subject vehicle, or any other vehicle, pedestrian, cyclist, or animal to avoid a crash. A rapid, evasive maneuver is defined as a steering, braking, accelerating, or any combination of control inputs that approaches the limits of the vehicle capabilities. Any event where the driver swerves off of the side of the road, and any part of the truck leaves the pavement, will automatically be coded as a near-crash.

> Crash-relevant conflict. Any circumstance that requires a crash avoidance response on the part of the subject vehicle, any other vehicle, pedestrian, cyclist, or animal that is less severe than a rapid evasive maneuver (as defined above), but greater in severity than a "normal maneuver" to avoid a crash. A crash avoidance response can include braking, steering, accelerating, or any combination of control inputs. A "normal maneuver" for the subject vehicle is defined as a control input that falls within the 99 percent confidence limit for control inputs for the initial study data sample. Examples of potential crash-relevant conflicts include hard braking by a driver because of a specific crash threat, or proximity to

other vehicles. Evasive maneuvers resulting in unsafe and/or illegal maneuvers or situations should be included in this category (or as near-crashes if more severe). Longitudinal decelerations of -0.35g or greater are reviewed to assess whether they qualify as crash-relevant conflicts (or near-crashes); those with decelerations of -0.50g or greater are always coded as crash-relevant conflicts or near-crashes.

All critical incidents were further divided into two categories: (i) drowsy-related critical incidents, and (ii) non-drowsy critical incidents. Hanowski et al. (2000) defined a drowsy-related critical incident as having a PERCLOS value greater than 0.08 (meaning that over a time period of 60 seconds, the driver's eyes were closed for at least 4.8 seconds or 8 percent of the time) or an Observer Rating of Drowsiness (ORD) (described below) value of greater than or equal to 40. PERCLOS is a mathematically defined eye-closure measure that has been demonstrated through direct measurement to correlate (at high values) with subject performance degradation under varying conditions of sleep deprivation (Wierwille, 1999a; 1999b; Wierwille et al., 2003).

According to Hanowski et al. (2000), these threshold values were set based on two criteria: (i) observing natural breaks in the data (when it was plotted across PERCLOS and ORD), and (ii) the opinion of Walter Wierwille, the developer of the PERCLOS and ORD assessment methodologies (Wierwille, 1999). Since PERCLOS was not found to be a reliable measure (the DDWS tested produced too many false alarms) drowsy-related critical incidents will be defined as a crash, near-crash or crash-relevant conflict in which the driver has an ORD of 40 or higher. ORD is described in more detail below.

Observer rating of drowsiness (ORD).

Observer Rating of Drowsiness (ORD) is a subjective rating of how drowsy the driver appears. Analysts view the video for one minute prior to the conflict then give a rating, on a likert-type scale with the following anchor points, Not Drowsy, Slightly Drowsy, Moderately Drowsy, Very Drowsy, and Extremely Drowsy. The procedure for measuring ORD was developed and first used by Wierwille and Ellsworth (1994). That study demonstrated that ORD could have good intra- and inter-rater reliability and that the measure correlated highly (r = +0.7 to 0.9) with eye closure measures such as PERCLOS (percentage of time that the eyes were closed 80 percent or more) and AVECLOS (mean percent eye closure). As mentioned above, ORD was used to define drowsy-related critical incidents.

Quantity of sleep.

Quantity of sleep is important to consider when assessing the 2004 revised HOS regulations. Increased off-duty time is a major change from the old HOS regulations and will hope to increase the quantity of sleep, therefore reducing levels of fatigue. Each participant was asked to wear an actigraph watch (Figure 2) at all times. This provided information as to the participant's sleep patterns and the amount of sleep received each night. Actigraphy is described in more detail below.

Figure 2. Actigraph watch worn by participants in the DDWS FOT.

Actigraphy is a measurement of one's sleep quantity and quality. An actigraph watch was worn by each participant on his/her non-dominant wrist and detected the amount of movement that he/she made, both during sleep hours and wake hours. When graphed, actigraphy allows researchers to see how long a driver slept during the night and the quality of their sleep. Quality of sleep can be determined by looking at the level of movement during the driver's sleep period. If there is a lot of body movement, then the driver may not have had very restful sleep. It is a useful measurement when researching sleep patterns and the effects that sleep has on a driver's performance. Figure 3 shows an example of the output data from an actigraph watch. Each row represents a 24-hour period of data starting at 12:00 pm. The arrow on line two (Wednesday, 4/13/05) indicates a period of sleep, evident by low activity level (i.e., the black bars are much shorter during this time period than during wake periods). The shorter periods of low activity indicate a nap or rest period.

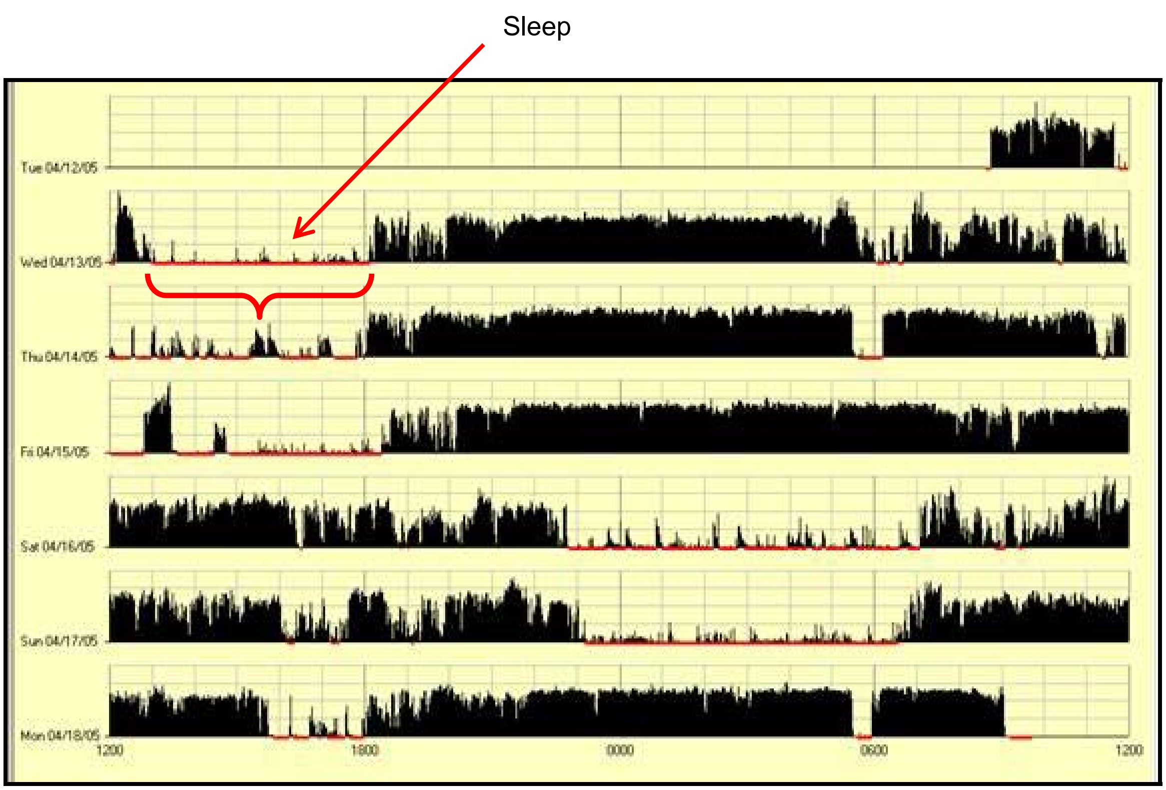

Figure 3. Example of output data from an actigraph watch.

At this time, it is unknown if the actigraphy data is accurate when compared to actual sleep time. However, VTTI is currently conducting a study in which drivers are asked to wear the actigraph watch for four consecutive weeks while simultaneously filling out a daily activity log. This will allow for a comparison of the actigraph data to self-reports of the drivers wake and sleep time.

Subjective Measures

Post-study questionnaire.

A questionnaire (APPENDIX A) was administered to each participant after he/she completed the data collection. The purpose of the questionnaire was to obtain drivers' opinions on the revised HOS regulations. Example questions include, "Do you think that it is important for professional drivers to follow hours-of-service regulations? (either old or revised)", "How well do you think you follow the revised hours-of-service regulations?", and "If you could change anything about the revised hours-of-service regulations, what would it be?". This information, along with the analysis of drowsy-related critical incidents, was used to develop guidelines and/or recommendations as to how the HOS may be revised to benefit the driver and to reduce drowsy-related critical incidents.

Data Collection Method

<u>Field Studies</u>

The data for this research was collected in a naturalistic setting. Naturalistic data collection is a type of field study and may also be referred to as observational research. Kerlinger (1964) defines field studies as "scientific inquiries aimed at discovering the relations and interactions among sociological, psychological, and educational variables in real social structures" (p.387). Kerlinger also states that field studies are aimed at observing situations and studying the "relations among the attitudes, values, perceptions, and behaviors of individuals and groups in the situation" (p.387).

In addition to a field study approach, the data collection was continuous from the time that the truck ignition was turned on until it was turned off. This allowed for a complete picture of what behaviors the driver was engaging in while driving the truck.

Field studies have several strengths (outlined by Babbie, 1992) to promote its use. It is appropriate to use a field study when the researcher wants to observe participant behaviors in a natural setting. From this, it is ideal to use a field study to observe drowsy-related critical incidents. In order to fully understand the behavior(s) that lead up to a critical incident, it is important to observe the behaviors in a natural environment (i.e., on a real road). It would not be practical to investigate critical incidents in a laboratory or simulator setting, for the participant may change his/her behavior because he/she knows that they are in a controlled setting. Field studies are also beneficial for the study of processes over time. When discussing drowsy-related critical incidents, field studies are appropriate because information may be gathered prior to the critical incident, such as the onset of drowsiness over time, along with information during the critical incident such as the evasive maneuver that the participant used or attempted to use. From this field study, an analysis on critical incidents and drowsy-related critical incidents was performed.

Data Collection Process

The data collection method presented in the following section is adapted from an earlier publication (Hanowski et al., September 2005) on the naturalistic data collection study that resulted in the data used for this research. The author of this research was also a co-author on this publication.

<u>Participants and Setting</u>

This research included data from 95 drivers (94 males, 1 female) that either completed the required number of weeks in data collection (up to 16 weeks) or withdrew from the study for one reason or another (e.g., terminated from the participating fleet). Each driver was required to have a Class-A Commercial drivers' license to participate.

Drivers volunteered and were chosen based on the following requirements: (i) a significant proportion (40% or more) of their driving was at night, (ii) they did not wear glasses while driving, and (iv) they passed vision and hearing tests. The first two qualifications were important for the FOT because the DDWS device that was tested did not work in the daytime or with drivers wearing glasses.

Drivers were employed at one of three fleets across nine different locations. Fleets A and B were line-haul operations, while Fleet C was involved in over-the-road, truckload operations. The mean age of drivers was 39.5 years old (Range: 24 – 60 years old). Sixty-two drivers identified themselves as Caucasian (65.1 percent), 30 African-American (31.6 percent), one Asian-American (1.1 percent), one Native-American (1.1. percent), and one Hispanic-American (1.1 percent). Participants indicated driving a commercial motor vehicle for an average of 125.6 months (Range: 15 – 504 months). Data were collected for a total of 34,260 hours of driving time (Mean hours per driver: 357 hours; Range: 14 – 920 hours).

IRB and Certificate of Confidentiality

An IRB form (APPENDIX B) was submitted to the Virginia Tech IRB and approved for the FOT data collection. The IRB form contains a detailed description of the experimental protocol that was used.

In addition, a Certificate of Confidentiality (APPENDIX C) was obtained from the Department of Health and Human Services.

Data Acquisition System (DAS)

There were three forms of data being collected by the data acquisition system (DAS): (i) video, (ii) dynamic performance, and (iii) audio. Data were continuously collected at approximately 4 MB/min. Each driver drove for approximately 60 hours in a seven-day period. The data used for this research totaled approximately 12 terabytes of data, 34,260 hours, and approximately 2.5 million miles of driving.

The DAS was active when the ignition system of the vehicle was turned on; therefore, the data were collected continuously whenever the truck was on and in motion. The system paused if the vehicle ceased motion for a 15 minutes or longer to reduce the amount of unusable data that was collected since drivers often leave their trucks running while they sleep or load/unload their trailers.

The DAS output three types of files, (i) video (.mpeg), (ii) performance data (.dat) obtained from dynamic sensors, and (iii) audio obtained from the incident box (.mp3). Each is described in more detail below.

Video Cameras

Digital video cameras were used to continuously record the driver and the outside driving environment. Four video cameras were multiplexed into a single image. The four camera views are: (1) forward, (2) driver's face, (3) rear-facing-left, and (4) rear-facing-right. The forward and rear-facing camera views provide good coverage of the driving environment. The face view provides coverage of the driver's face and eyes and allows the analyst to provide subjective drowsiness ratings (ORD) of the driver. Figure 4 shows the camera direction and approximate fields-of-view for the four cameras.

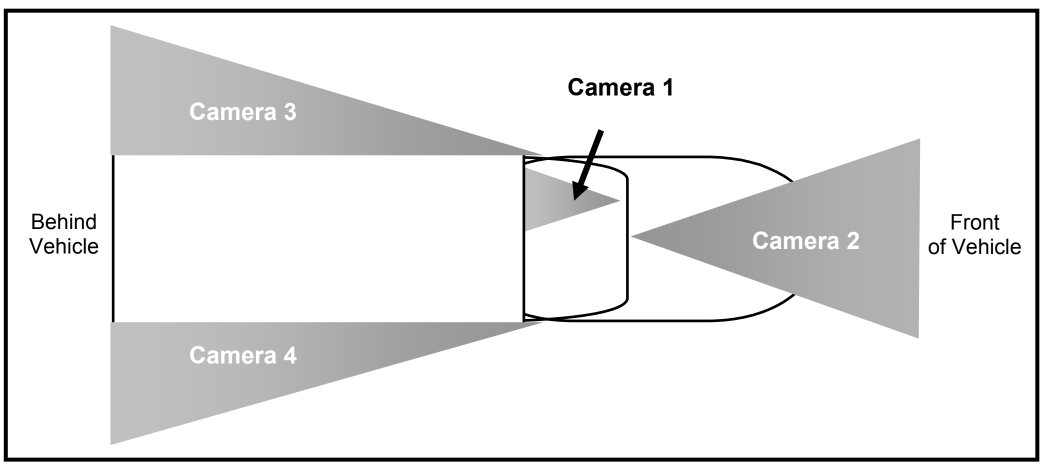

Figure 4. Camera directions and approximate fields of view.

As shown in Figure 5, the four camera images were multiplexed into a single image. A time-stamp (frame number) was also included in the video file but was not displayed on the screen. The frame number was used to time-synchronize the video and the truck performance data.

Figure 5. Split-screen presentation of the four camera views.

Note: Image shown is that of a VTTI employee, not a participant from the naturalistic study.

Dynamic Sensors

X/Y accelerometer.

Accelerometers were instrumented in each truck and were used to measure longitudinal (x) and lateral (y) accelerations. This sensor proved very useful and captured many critical incidents when the driver had to brake hard. Although the lateral (y) accelerometer data were available, it was not used in the analysis because it did not provide any useful data.

Yaw rate.

A yaw rate (gyro) sensor was included in the DAS and provided a measure of steering instability (i.e., jerky steering movements). This sensor was used to capture critical incidents when the driver began to veer off the side of the road and had to swerve quickly to return to his/her lane.

Front VORAD.

A radar-based forward-object detection unit was installed on the front of the truck (Figure 6) and provided a measure of range to lead vehicles. From the range measure, time-to-collision (TTC) was also derived. Time-to-collision is a measure of how many seconds before two vehicles would collide if one of the vehicles did not perform an evasive maneuver. The VORAD unit was used for passive data collection and did not display information to the driver.

Figure 6. VORAD unit on the front of the truck.

Vehicle network.

The vehicle network refers to a from-the-factory on-board data collection system installed on each truck. Depending upon the truck model, year, and manufacturer, there are several data network protocols or standards that are used with heavy-vehicles, including those defined by J1708 (SAE, 1993), J1939 (SAE, 2001), and J1587 (SAE, 2002). An interface was developed to access the data from the network and merge it into the performance data file. Some of the typical measures found on the vehicle network of most trucks include, but are not limited to: vehicle speed, distance since vehicle start-up, throttle position, brake pressure and right/left turn signals.

Incident Box

Incident pushbutton.

When the driver was involved in a critical incident, he/she was instructed to push a red button on the Incident Box (Figure 7). This button opened an audio channel for 20 seconds. In this time, the driver provided a verbal report of what occurred. Drivers were reminded approximately once a week to use the incident pushbutton.

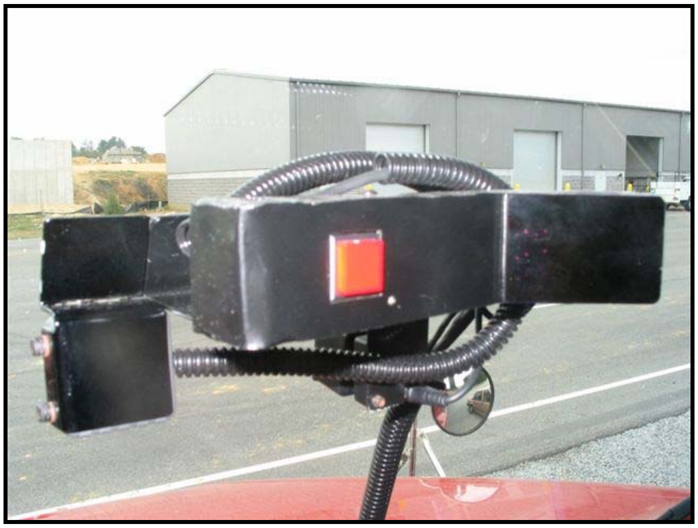

Figure 7. Incident box.

Data Reduction Process

The data reduction process presented in the below section is adapted from an earlier publication (Hickman et al., 2005) on the naturalistic data collection study that resulted in the data used for this research. The author of this research was also a co-author on this publication.

A data reduction software program was developed by VTTI for use on all analysis projects. This software program was used to conduct the data reduction and analysis for this research. The following sections provide details of this software, including screen shots of the user interface, and the process used to conduct data reduction.

There were three primary steps in performing the data reduction for this research: (i) run the critical incident trigger program, (ii) check the validity of the triggers, and (iii) give an observer rating of drowsiness (ORD) on the necessary critical incidents. Each step is described in detail below.

Running the Critical Incident Trigger Program

The first step in the data reduction process was to identify critical incidents of interest, including crashes, near-crashes, and crash-relevant conflicts (defined in the Experimental Design section). To do this, triggers (Table **7**) were created to flag points of interest in the data such as hard braking, quick steering maneuvers and short times-to-collisions. There were three steps taken to determine the optimum trigger value; each step is listed in detail below.

Step 1: Start with trigger values from the 100-Car study. The 100-Car study (Dingus et al., 2005) used modified triggers from previous VTTI data collections (Dingus et al., 2002; Hanowski et al., 2000). Since the 100-Car study instrumented light vehicles, it was necessary to modify the trigger values when looking at data from heavy vehicles since braking and steering values differ greatly. For example, a normal braking value in a light vehicle may equal -0.7 g or higher, while a normal braking value in a heavy vehicle may equal -0.4 g. Therefore, beginning trigger values were suggested from the software developer based on his knowledge of the 100-Car study and of the early data collected from the heavy vehicles. From the initial suggested values, other values, within a close range, were chosen for testing; this process is described below.

Step 2: Trial and error testing with different trigger values. Once a 'beginning' value was determined for each trigger, four other values (two lower values and two higher values) were chosen and used for testing. For example, consider the Longitudinal Acceleration trigger (hard braking). The suggested value for this trigger was |0.30g|; therefore the four other values used in the testing were |0.20g|, |0.25g|, |0.35g|, and |0.40g|. To test these values, a sample set of data were used and triggers were created for each of the five values. The results from this are shown in Table 6. The same process was repeated for the Swerve trigger and the Time-to-Collision trigger. The next step was to view each trigger and check for valid events; this process is described below.

Table 6. Summary of trigger values and number of triggers created during trigger testing.

Trigger Type	Trigger Value	Number of Triggers (Valid and Invalid)
LA (1)	|0.25 g|	164
LA (2)	|0.30 g|	63
LA (3)	|0.35 g|	23
LA (4)	|0.40 g|	10
LA (5)	|0.45 g|	3
TTC (1)	1.80 s	52
TTC (2)	1.85 s	60
TTC (3)	1.90 s	70
TTC (4)	1.95 s	82
TTC (5)	2.00 s	96
Swerve (1)	| 1.5 rad/sec^2|	171
Swerve (1)	| 2.0 rad/sec^2|	53
Swerve (1)	| 2.5 rad/sec^2|	22
Swerve (1)	| 3.0 rad/sec^2|	12
Swerve (1)	| 3.5 rad/sec^2|	4

Step 3: View triggers and determine optimum value for each trigger type. Next, the author of this research viewed each trigger created (for all five values of each trigger type) to determine if the trigger value produced a valid trigger or a false alarm. If the trigger value was set too low, too many false alarms would be produced, causing the analyst's extra time in viewing the triggers for the entire data set. If the trigger value was set too high, it was possible to miss critical incidents that had a dynamic sensor value that was under the set threshold. Therefore, it was important to find an optimum trigger value that would produce the smallest number of false alarms and the smallest number of missed critical incidents. The final values chosen are those shown in Table **7** below.

Table 7. Triggers and trigger values used to identify critical incidents.

Trigger Type	Definition	Description
Longitudinal Acceleration	Hard braking or sudden acceleration	(1) Acceleration or deceleration greater than or equal to $\lvert 0.35g \rvert$. Speed greater than or equal to 15 mph. (2) Acceleration or deceleration greater than or equal to $\lvert 0.5g \rvert$. Speed less than or equal to 15 mph.
Time-to-Collision	The amount of time (in seconds) that it would take for two vehicles to collide if one vehicle did not perform an evasive action	(3) A forward time-to-collision value of less than or equal to 1.8 seconds, coupled with a range of less than or equal to 150 feet, a target speed of greater than or equal to 5 MPH, a yaw rate of less than or equal to $\lvert 4°/sec \rvert$, and an azimuth of less than or equal to $\lvert 0.08° \rvert$.
Swerve	A sudden "jerk" of the steering wheel to return the truck to its original position in the lane.	(4) Swerve value of greater than or equal to $\lvert 3\ rad/sec^2 \rvert$. Speed greater than or equal to 15 mph.
Critical Incident Button	A self-report by the driver of an incident.	(5) Activated by the driver upon pressing a button, located by the driver's visor, when an incident occurred that he/she deemed critical.
Analyst Identified	An event that is identified by the analyst but has not been identified by any other trigger.	(6) Event that was identified by a data analyst viewing video footage; no other trigger listed above identified the event (i.e., Longitudinal Acceleration, Time-to-Collision, etc.).

Once the above trigger values were set, the entire set of data were run through the data viewing/reduction software in order to create triggers. Since there was such a large amount of data collected at one time, the data were run through the software program approximately once every two weeks so that the number of triggers that the analysts had to view was reasonable. A total of 28,769 triggers were created from the data set (May 2004 to May 31, 2005).

Checking the Validity of the Triggered Events

Once the triggers were created, the next step in the data reduction process was to have analysts view each trigger to determine if it was a valid trigger; this process is explained below. As the triggers were created a 90-second epoch was created around each trigger; (1 minute prior to trigger, 30 seconds after trigger). An epoch allows the analyst to look at a small amount of time in the video instead of opening the entire 45-minute video file. Figure 8 is an example of a swerve trigger and the surrounding epoch.

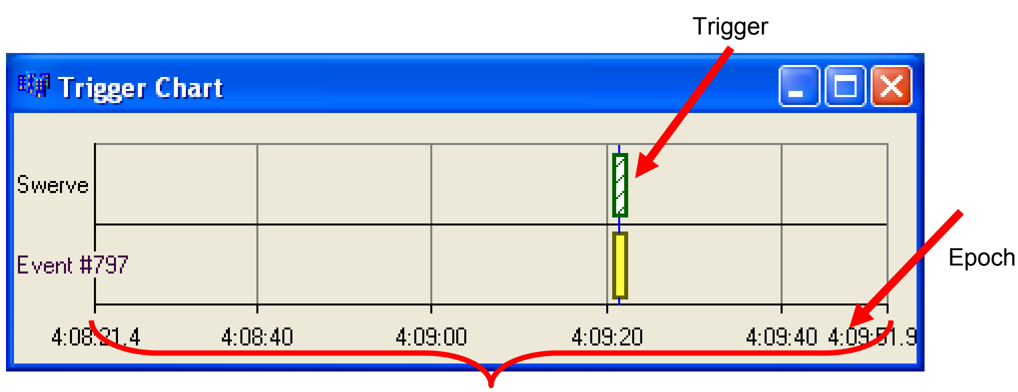

Figure 8. Example of a trigger and epoch.

After the triggers were created, each one was viewed to determine if it was *valid*, or *invalid*. Figure 9 shows how the triggers are classified. Each category is described in more detail below.

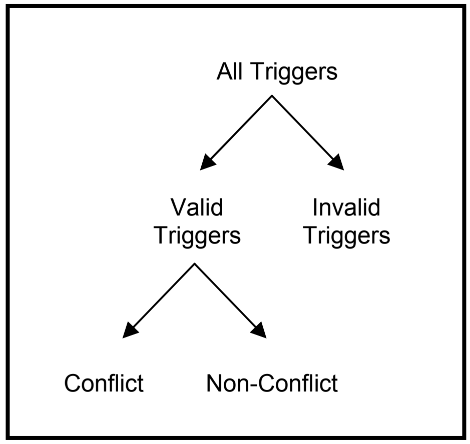

Figure 9. Diagram of the trigger classification.

Valid triggers are those in which the dynamic sensor data is correct, below (or above) the threshold value, and can be verified by the video. To determine the validity of the triggers, data analysts were trained to observe the recorded video and data plots of the various sensor measures associated with each 90-second epoch. Once it was determined that the trigger was valid, it was determined if the valid trigger was a *conflict* or *non-conflict*. Conflicts, (i.e., critical incidents) resulted when the dynamic sensor data were correct and the behavior of the participant was part of a traffic safety event (e.g., the driver had to brake hard to avoid another vehicle changing lanes too close in front). The author of this research reviewed each conflict (i.e., critical incident) to confirm its validity.

Figure 10 shows an example of a valid trigger for Longitudinal Acceleration (LA). In this example, the Trigger Chart shows the trigger at the point where the Accel_X plot value reaches -0.37g indicating a sharp deceleration of the vehicle. For this example, the LA trigger was set at |0.35g| so anytime the software detected an LA with a magnitude greater than |0.35g|, a trigger was created. Looking closely at the video in the top right quadrant, a vehicle can be seen in front (and to the right) of the subject vehicle. At this point, a tractor-trailer has begun to change lanes (to the left) directly into the lane in front of the instrumented vehicle and the driver of the instrumented truck brakes to avoid the truck.

Figure 10. Example of a validated trigger where the LA was less than the pre-set value of |0.35g|.

Note: The image of the participant has been obscured to protect their identity.

Non-conflict triggers resulted when the threshold values were set ineffectually and did not result in a traffic safety event. Figure 11 shows an example of a non-conflict that had a valid Swerve (quick steering) trigger. During this time, the driver of the instrumented truck was changing lanes. The Trigger Chart shows that the trigger appeared when the Swerve value reached 3.68 rad/sec^2 (the value for this trigger was set at $\geq$ |3.0 rad/sec^2|). After reviewing the video, it was seen that there were not any vehicles in front of or to the side of the instrumented vehicle and he was simply changing lanes.

Figure 11. Example of a non-conflict event (with a valid trigger) where the driver's swerve (quick steering) value was 3.68 (trigger set to ≥ 3).

Note: The image of the participant has been obscured to protect their identity.

Invalid triggers are those which the dynamic sensor data were incorrect (e.g., the forward vorad detected a bridge as a target vehicle) or gave a spurious reading. Once triggers were marked as invalid, they were not reviewed any further.

Observer Rating of Drowsiness

The next step in the data reduction process was to give an ORD for all events for which it was possible (i.e., the driver is not wearing sunglasses, the video is not too dark, and there were the necessary 30 seconds of video prior to the trigger). To provide an ORD rating an analyst was instructed to watch the driver's face and body language for one minute prior to the trigger and use the rating scale shown in Figure 12 to record an ORD value. In order to reduce subjective differences between analysts, the author of this research provided the ORD rating for all events. As described by Wierwille and Ellsworth (1994), signs indicative of drowsiness include rubbing the face or eyes, facial contortions, moving restlessly in the seat, and slow eyelid closures. The analyst was trained to look for these signs of drowsiness and make a subjective, but specific assessment of the level of drowsiness. The rating scale used by Wierwille and Ellsworth was printed on paper and analysts in that study marked a point on the horizontal line. For this study, the analyst moved a cursor on a computer monitor to the desired ORD level (shown in Figure 12 below). The ORD value was recorded using a 100-point continuous rating scale where a number from 0 to 100 was assigned based on the linear position chosen by the analyst.

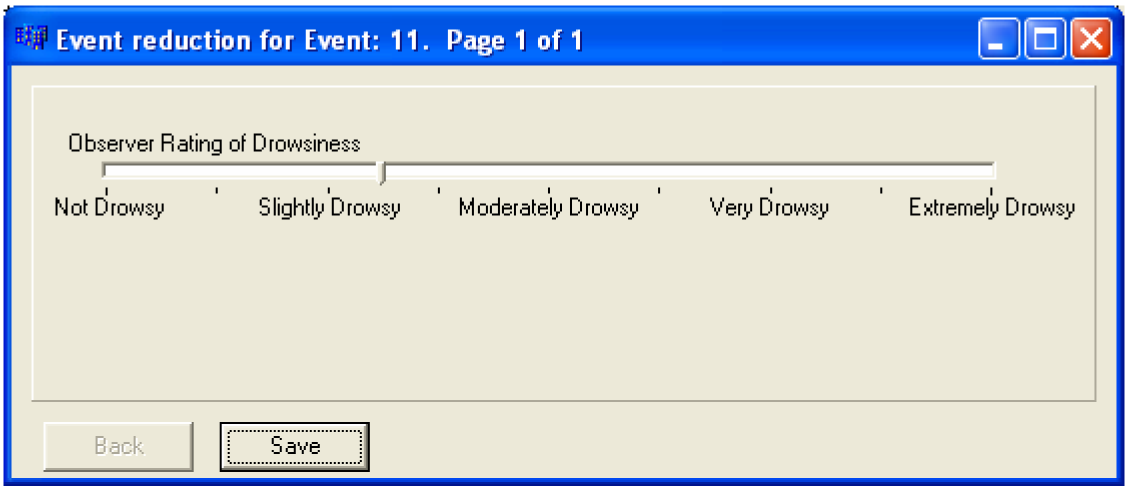

Figure 12. ORD rating scale used by data analysts (adapted from Wierwille and Ellsworth, 1994). Reprinted by permission.

CHAPTER 4: RESULTS AND DISCUSSION

It was hypothesized that the revised HOS regulations would benefit the commercial motor-carrier industry by improving safety and allowing drivers to work and rest on a more natural 24-hour cycle. Naturalistic data were collected from 103 drivers (data from 95 of the drivers are included in this research) while they worked their normal schedules; this included both video and sensor data. In addition 78 drivers filled out a short subjective questionnaire pertaining to the revised HOS regulations. The results can be found in this chapter.

A total of 915 valid critical incidents were identified in the data by the triggers described in Table **7**. It should be noted that the Incident Pushbutton trigger did not provide any useful data as the drivers primarily used this as a means to complain about other traffic or to try to alert employees at VTTI to equipment failures. It was hoped that drivers would provide an explanation as to the reason for the critical incident (e.g., drowsy, distracted), but this was not the case.

Table 8 shows a breakdown of all critical incidents by fault; that is, which party involved in the incident appeared to be the cause of the incident.

Table 8. Critical incidents by fault.

At-Fault	Number of Critical Incidents	Percent of Critical Incidents
Heavy-vehicle driver (Participant)	680	74.3%
Other vehicle driver	197	21.5%
No fault	35	3.8%
Unknown	3	0.3%
Total	915	100.0%

Previous research conducted by VTTI (Hanowski et al., 2000) has found that the "other driver" (i.e., non-participant driver) was most often at fault (55%) when compared to the study participant (31%). This was not the case for this study. Because the trucks involved in the FOT changed trailers daily, it was not possible to put cameras on the rear of the trucks to capture data from behind. This led to a high proportion of participant driver at-fault critical incidents because it was only possible to capture data from in front of the instrumented truck. The video usually involved the participant driver braking suddenly behind a lead vehicle, or driving too closely behind a lead vehicle. Since the following vehicle is required to leave adequate following distance between themselves and the lead vehicle, these scenarios would likely result in the following vehicle (i.e., the instrumented truck) being at fault. Since there was not any data collected from behind the instrumented truck, it was not possible to collect data on scenarios where the instrumented truck was the lead vehicle and the other vehicle (i.e., following vehicle) was at fault. Because of this, the camera placement and views may have contributed to the "at-fault" assignment as this study did not have 360° monitoring cameras. Only participant driver at-fault critical incidents were used in the analysis.

For the purpose of this research, a vehicle (or object) was considered to be at fault if that vehicle (or object) was assigned the *critical reason for the critical event.* The critical reason for the critical event is a variable used in the Large Truck Crash Causation Study (LTCCS) (Blower and Campbell, 2002). This variable was chosen so that comparisons could be made across the LTCCS data and the DDWS FOT data. The options for the critical reason for the critical event are listed below.

DRIVER RELATED FACTOR: Critical Non-Performance Errors

- Sleep, that is, actually asleep
- Heart attack or other physical impairment of the ability to act
- *Drowsiness, fatigue, or other reduced alertness (not asleep)*
- Other critical non-performance
- Unknown critical non-performance

DRIVER RELATED FACTOR: Recognition Errors

- Inattention (i.e., daydreaming)
- Internal distraction
- External distraction
- Inadequate surveillance (e.g., failed to look, looked but did not see)
- Other recognition error
- Unknown recognition error

DRIVER RELATED FACTOR: Decision Errors

- Too fast for conditions (*e.g., for safe vehicle control or* to be able to respond to unexpected actions of other road users)
- Too slow for traffic stream
- Misjudgment of gap or other's speed
- Following too closely to respond to unexpected actions (close proximity for 2 or more seconds)
- False assumption of other road user's actions
- Illegal maneuver
- *Apparently intentional sign/signal violation*
- *Illegal U-turn*
- *Other illegal maneuver*
- Failure to turn on head lamps
- Inadequate evasive action (e.g., braking only not braking and steering; *release accelerator only instead of braking*)
- *Aggressive driving behavior: Intimidation: any behavior emitted by a driver while driving that is intended to cause physical or psychological harm to another person.*
- *Aggressive driving behavior: Wanton, neglectful or reckless behavior: excessive risky driving behaviors performed without intent to harm others, such as weaving through traffic, maneuvering without signaling, running red lights, frequent lane changing, and tailgating*
- Other decision error
- Unknown decision error

DRIVER RELATED FACTOR: Performance Errors

- Panic/Freezing
- Overcompensation
- Poor directional control, e.g., failing to control vehicle with skill ordinarily expected
- Other performance error
- Unknown performance error
- Type of driver error unknown

VEHICLE RELATED FACTOR

- Tires/wheels failed
- Brakes failed
- Steering failed
- Cargo shifted
- Trailer attachment failed
- Suspension failed
- Lights failed
- Vehicle related vision obstructions
- Body, doors, hood failed
- Jackknifed

- Other vehicle failure
- Unknown vehicle failure

ENVIRONMENT RELATED FACTOR: Highway Related
- Signs/signals missing
- Signs/signals erroneous/defective
- Signs/signals inadequate
- View obstructions by roadway design
- View obstructed by other vehicles crash circumstance
- Road design - roadway geometry (e.g., ramp curvature)
- Road design - sight distance
- Road design - other
- Maintenance problems (potholes, deteriorated road edges, etc.)
- Slick roads (low friction road surface due to ice, loose debris, any other cause)
- Other highway-related condition

ENVIRONMENT RELATED FACTOR: Weather Related
- Rain, snow
- Fog
- Wind gust
- Other weather-related condition

ENVIRONMENT RELATED FACTOR: Other
- Glare
- Blowing debris
- *Animal in roadway (no driver error)*
- *Pedestrian or pedal cyclist in roadway (no driver error)*
- *Object in roadway (no driver error)*
- Other sudden change in ambience
- Unknown reason for critical event

* Note: Options in *italics* were added specifically for use in the DDWS FOT study and are not part of the original LTCCS. Options in gray were used in the original LTCCS and were not used in the DDWS FOT study.

If one of the above Driver Related Factors was chosen for the participant driver, then that driver was considered to be at fault. If one of the above Driver Related Factors was chosen for the other vehicle driver, or if 'Animal in roadway, Pedestrian/pedalcyclist in roadway or Object in roadway' was chosen, then the participant driver was not considered to be at fault. If one of the environmental related factors was chosen (for any vehicle) then it was considered to be neither vehicle's fault.

Since the analysis compared drowsy-related critical incidents, (defined as having an ORD of 40 or greater), to non-drowsy critical incidents, and drowsy-related baseline incidents to non-drowsy baseline incidents (baseline incidents are explained below), some critical incidents, and baseline incidents, were omitted due to the fact that it was not possible to obtain an ORD. This could have occurred for several reasons such as: the driver was wearing sunglasses, the video was too dark to see the driver's face clearly, or there was not the required 30 seconds of video prior to the event.

Therefore, a total of 534 critical incidents (where the participant driver was at-fault and it was possible to obtain an ORD measure), were used in the analysis. In addition, 885, out of 1,072, baseline incidents were used, for a total of 1,419 incidents used in the analysis. Baseline incidents are random 1-minute epochs retrieved from the data and are intended to represent 'normal' driving by the participant. Approximately one baseline incident was retrieved for each week of driving for each participant. Table 9 provides a summary of all incidents by severity (definitions of each are provided in Chapter 3) and drowsiness level. Of these 534 critical incidents, 175 (33%) were considered to be drowsy-related critical incidents (i.e., ORD $\geq$ 40).

Table 9. Breakdown of all incidents by severity and drowsiness level.

Severity		Drowsy-Related Incidents	Non-Drowsy Incidents	Total Number of Incidents	Total Percent of Incidents
Critical Incidents	Crash	0	6	6	0.42%
	Crash: Tire Strike	1	4	5	0.35%
	Near-Crash	14	30	44	3.10%
	Crash-Relevant Conflict	160	319	479	33.76%
Baselines	Baselines	297	588	885	62.37%
Total		472	947	1419	100.0%

A Spearman Rho correlation was run using SAS to determine if there was a relationship between severity level (crash, crash: tire strike, near-crash, crash-relevant conflict and baseline) and ORD (0 – 100). The results showed no correlation between the two variables r_s (1417) = -0.04; p = 0.8518. As previously mentioned, one possible explanation for this is the low exposure to night time driving when drivers may be drowsier.

The remainder of this results section will answer the following three research questions.

1. Under what time-related conditions do drowsy-related critical incidents occur?
2. Are drivers getting more sleep under the revised HOS regulations?
3. What are drivers' opinions of the revised HOS regulations?

Research Question 1: Under what time-related conditions do drowsy-related critical incidents occur?

In order to answer the first research question, odds ratios were calculated for each variable of interest. Odds ratios are used for 2 x 2 contingency tables and "makes clear the degree to which one variable influences another" (Howell, 2002; p.165). The odds ratios were calculated as follows:

Table 10. 2 x 2 contingency table.

	Critical Incidents	Baseline Incidents
Drowsy	a	b
Non Drowsy	c	d

$$\text{Odds Ratio} = \frac{ad}{bc}$$

In addition, upper and lower confidence limits were calculated to determine if the odds ratios were statistically significant. These calculations are shown below:

$$\text{Upper Confidence Limit} = OR \times e^{1.96 \times \sqrt{\frac{1}{a}+\frac{1}{b}+\frac{1}{c}+\frac{1}{d}}}$$

$$\text{Lower Confidence Limit} = OR \times e^{-1.96 \times \sqrt{\frac{1}{a}+\frac{1}{b}+\frac{1}{c}+\frac{1}{d}}}$$

The results from these calculations can be found in APPENDIX D. Six different variables were used in this analysis:

- Time of day – The time of day that the critical incident occurred, determined from the DAS computer
- Day of week – The day of the week (Sunday – Saturday) on which the critical incident occurred

- Driving hour – The number of hours that the driver had been driving since the start of his/her shift
- Shift hour – The number of hours that the driver had been on duty (includes driving and non-driving work) since the start of his/her shift
- Day of shift – The number of consecutive days that the driver had been on duty without taking a minimum 34-hour break
- Time since last break – The number of hours since the driver last took a break (i.e., since the truck speed = 0)

The last four variables listed above (driving hour, shift hour, day of shift and time since last break) were obtained using a software program developed by VTTI. This software program made it possible to record how long the driver had been driving at any given time; the program assumed that any time the truck speed was greater than 0, the driver was driving, and any time the truck speed was equal to 0, the driver was taking a break. The software ignored any time that the speed dropped to 0 for less than ten minutes so that when the driver stopped at a traffic light, or in heavy traffic, the software did not consider it a break. It is important to point out a number of caveats with regard to the data obtained from this software:

- There are only driving files; there is no record of non-driving work activity.
- Embedded in breaks are non-driving work; there is no way to separate non-driving work from rest breaks as there is only a record of driving.
- In searching for the start of a work "week," the software program searched for non-driving segments of 34+ hours and assumed this is the restart break (it is unknown if this non-driving break includes non-driving work).
- The program searched the data for 6+ hour gaps in the driving files and assumed that the driver had a break. The next driving file, as long as it was not less than 14 hours from the start of the previous driving cycle, was considered the start of the next driving cycle.
- For any shift, it is not known if the system did not collect data.

- Data files without matching electronic and video files were removed as the specific driver could not be verified (Hanowski et al., June 2005)

The tables below show few significant odds ratios. In order to reduce analyst variability, all ORD measures were determined by the author of this research. In addition, only participant driver at-fault critical incidents were used. As such, the lack of significant results was likely due to a small sample and not due to biased data; this can be seen from the Cochran-Mantel-Haenszel Power Analysis explained later in this chapter.

Time of day (Figure 13) proved to be significant for the times 14:00 – 14:59 since '1' was not included between the lower and upper confidence limits. Sleep research shows that the circadian rhythm low falls between hours of 2:00 pm and 4:00 pm (Stutts et al., 1999), but it is not possible to say that the circadian rhythm is in fact the cause for these drowsy-related critical incidents. However, this is an interesting finding nonetheless and may have been influenced by the circadian rhythm low.

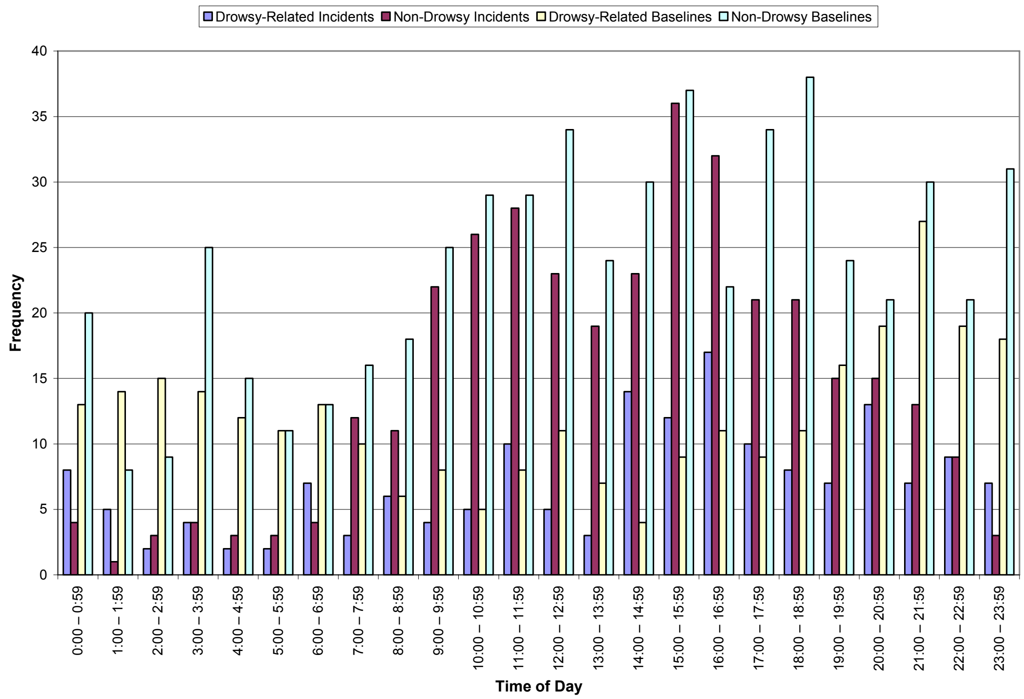

Figure 13. Frequency of Drowsy-Related Events, Non-Drowsy Events, Drowsy-Related Baselines and Non-Drowsy Baselines by Time of Day.

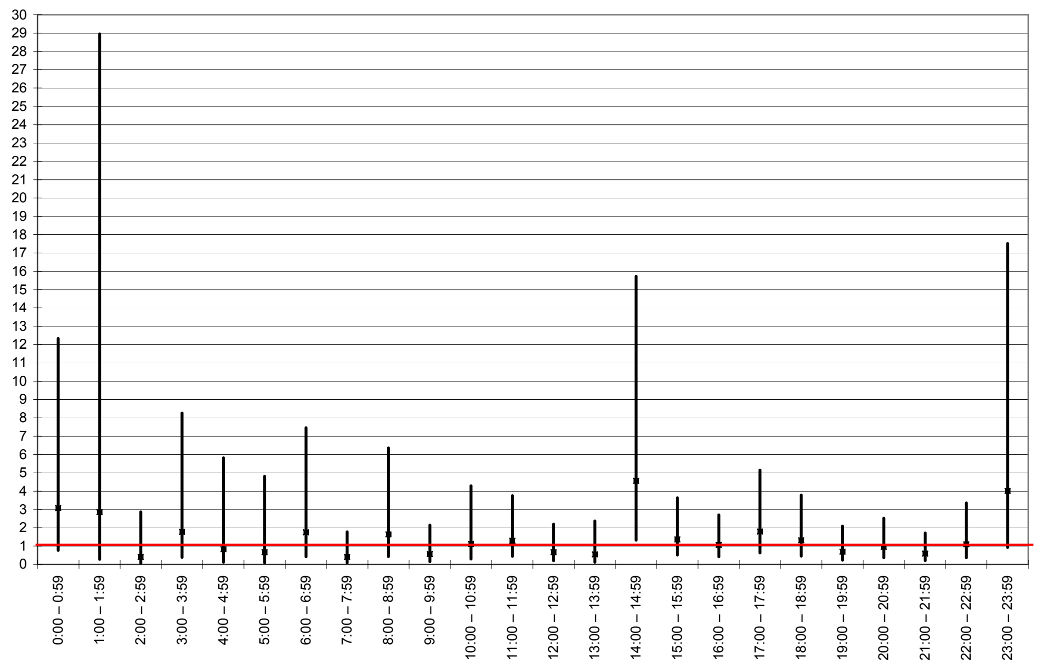

Figure 14. Odds Ratio of Drowsy-Related Events, Non-Drowsy Events, Drowsy-Related Baselines and Non-Drowsy Baselines by Time of Day.

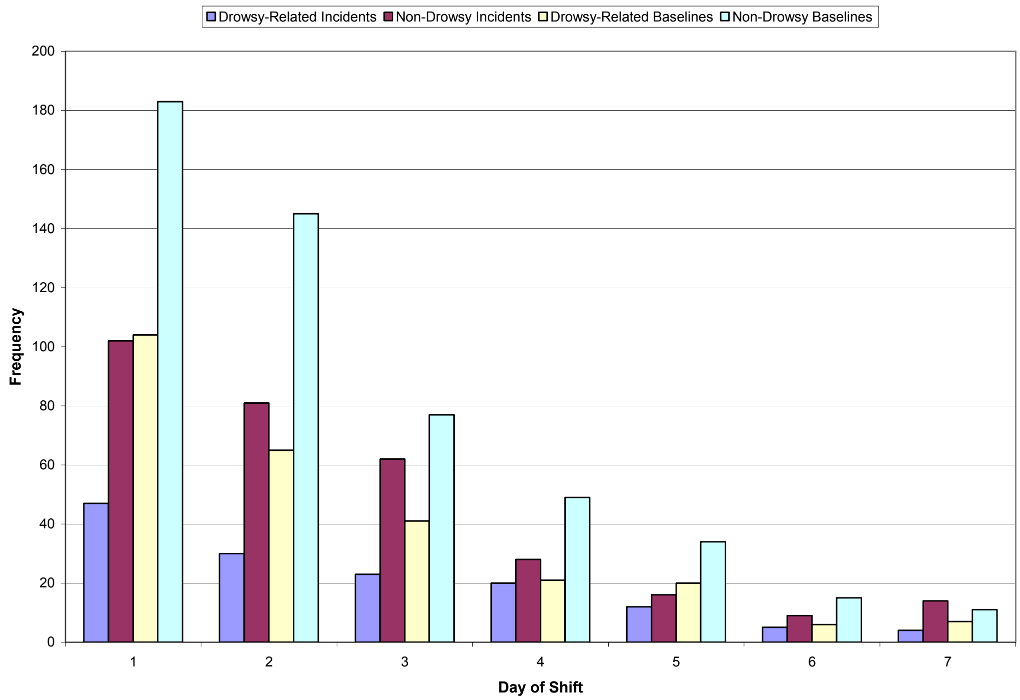

Figure 15. Frequency of Drowsy-Related Events, Non-Drowsy Events, Drowsy-Related Baselines and Non-Drowsy Baselines by Day of Shift.

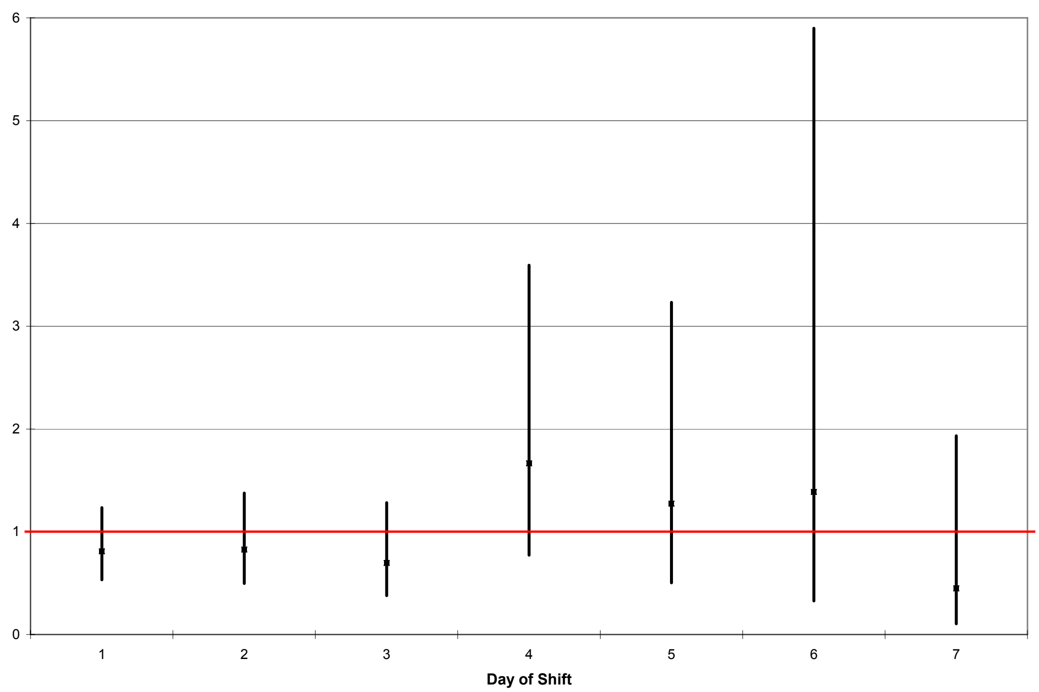

Figure 16. Odds Ratio of Drowsy-Related Events, Non-Drowsy Events, Drowsy-Related Baselines and Non-Drowsy Baselines by Day of Shift.

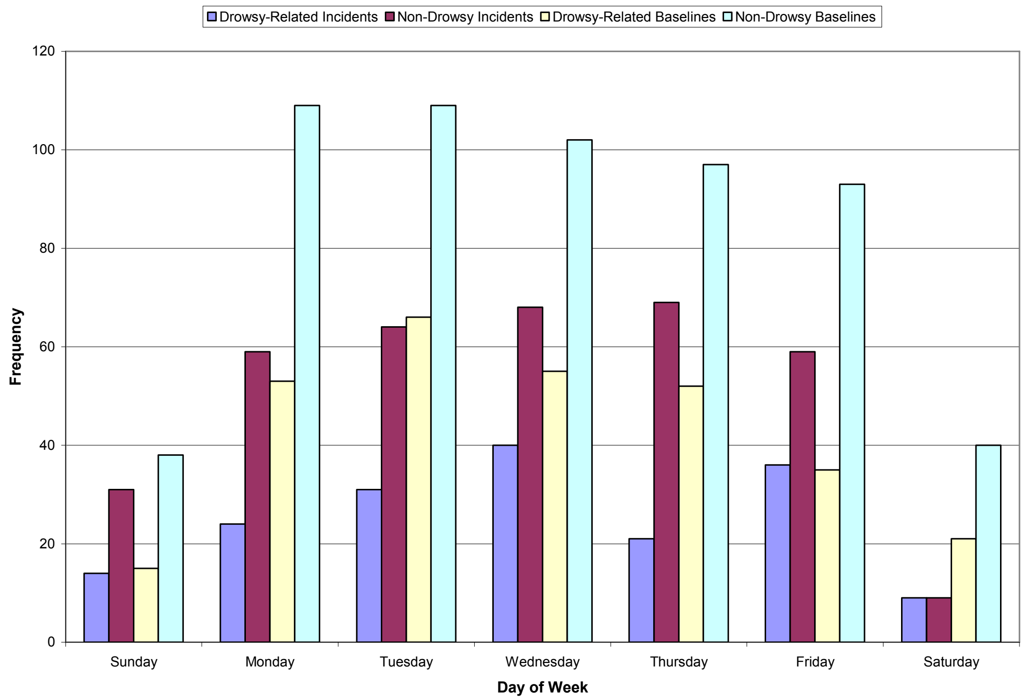

Figure 17. Frequency of Drowsy-Related Events, Non-Drowsy Events, Drowsy-Related Baselines and Non-Drowsy Baselines by Day of Week.

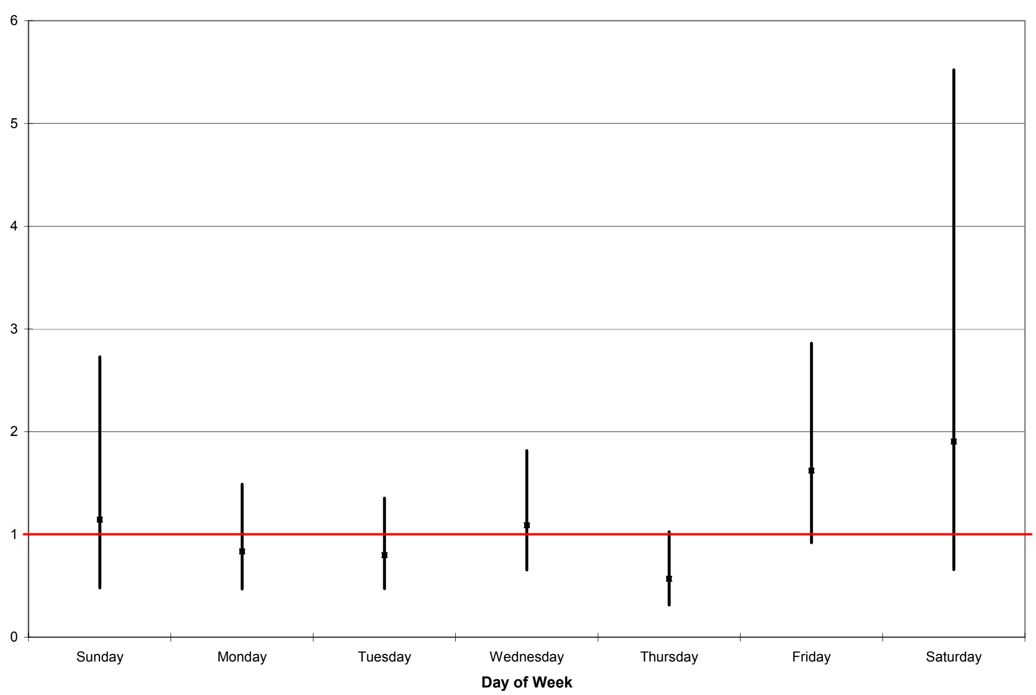

Figure 18. Odds Ratio of Drowsy-Related Events, Non-Drowsy Events, Drowsy-Related Baselines and Non-Drowsy Baselines by Day of Week.

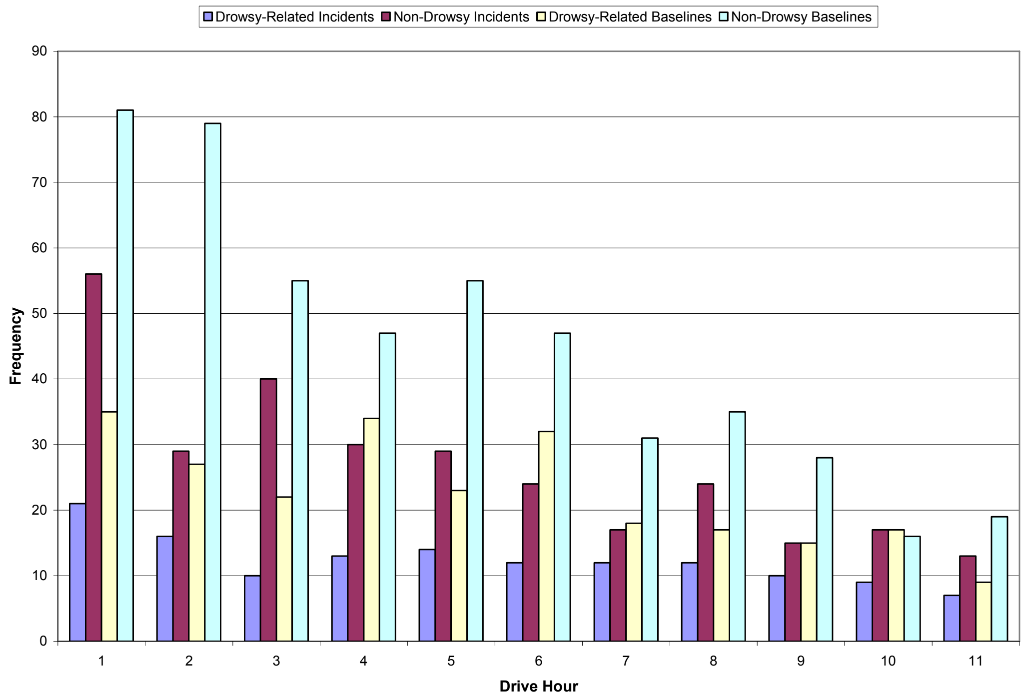

Figure 19. Frequency of Drowsy-Related Events, Non-Drowsy Events, Drowsy-Related Baselines and Non-Drowsy Baselines by Drive Hour.

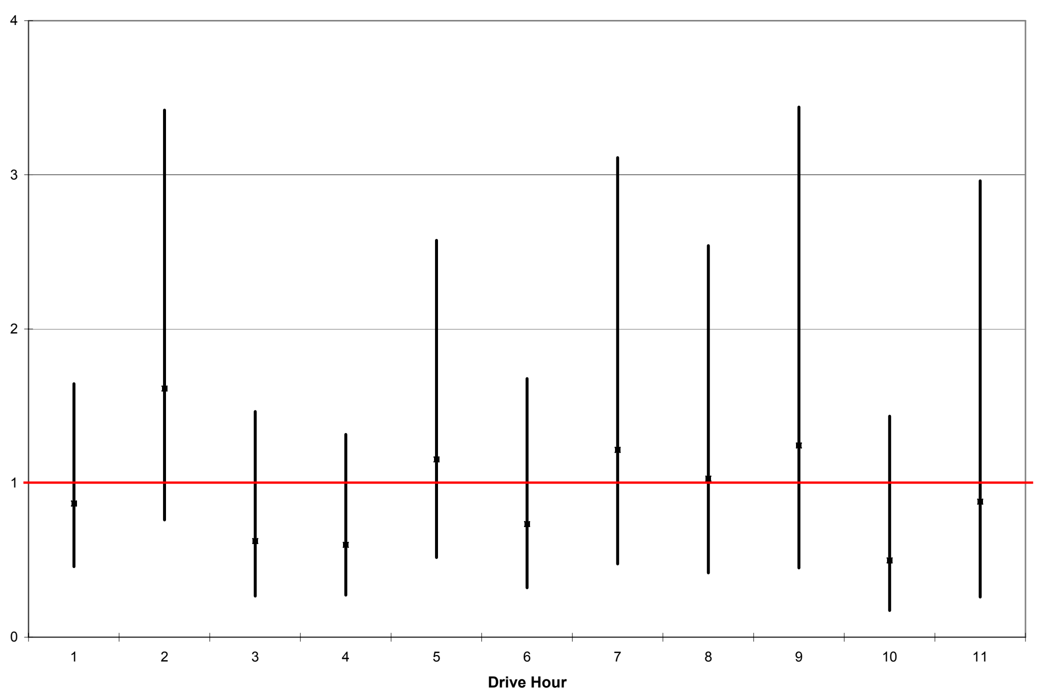

Figure 20. Odds Ratio of Drowsy-Related Events, Non-Drowsy Events, Drowsy-Related Baselines and Non-Drowsy Baselines by Drive Hour.

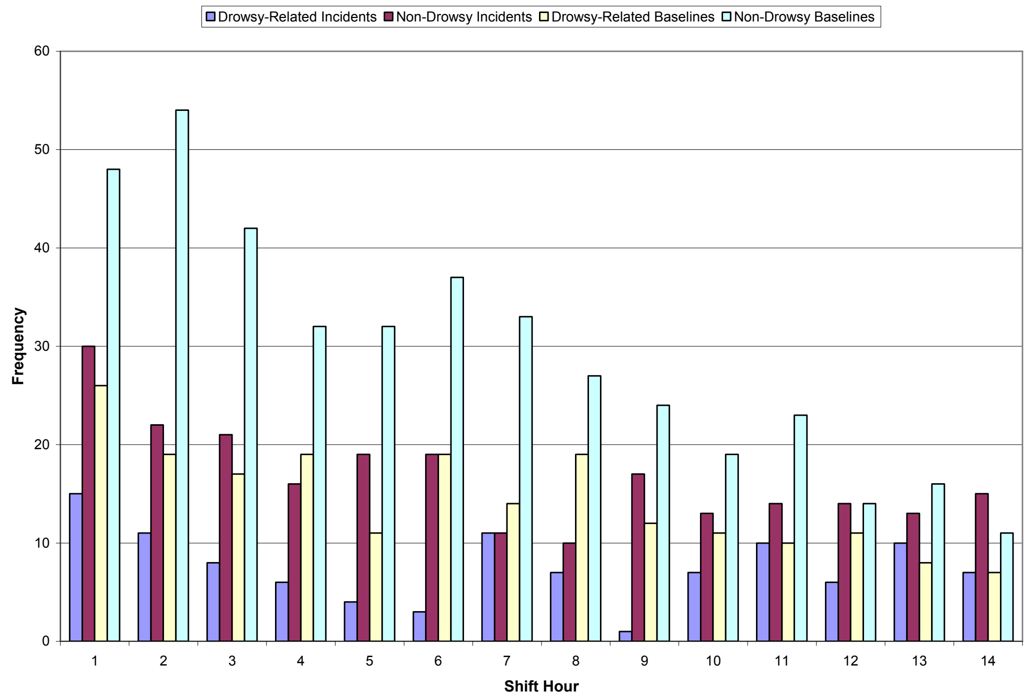

Figure 21. Frequency of Drowsy-Related Events, Non-Drowsy Events, Drowsy-Related Baselines and Non-Drowsy Baselines by Shift Hour.

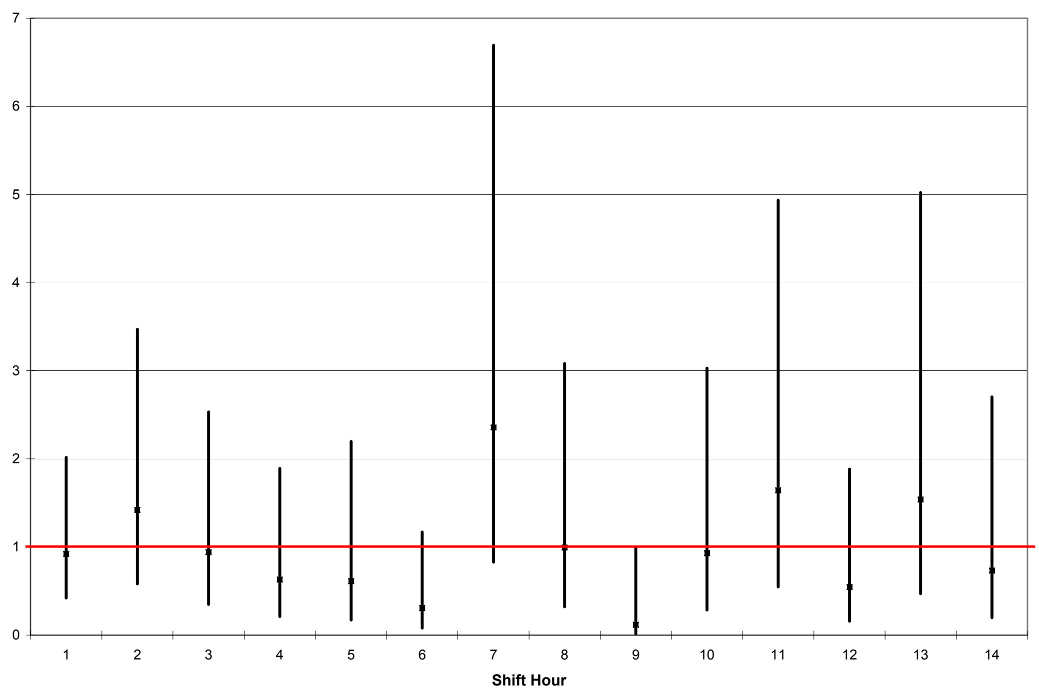

Figure 22. Odds Ratio of Drowsy-Related Events, Non-Drowsy Events, Drowsy-Related Baselines and Non-Drowsy Baselines by Shift Hour.

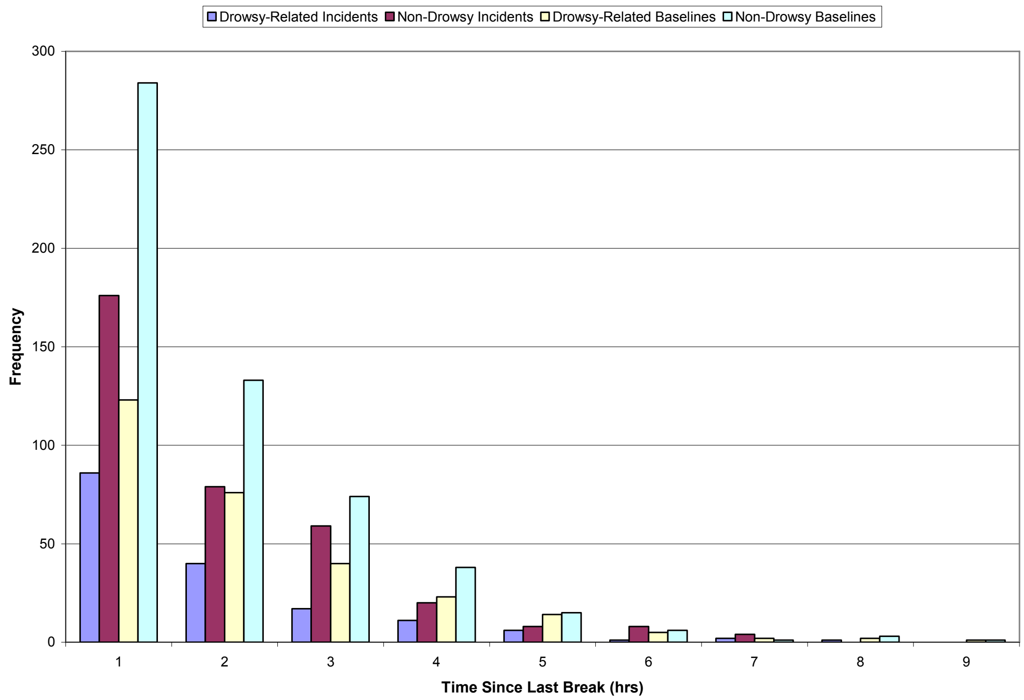

Figure 23. Frequency of Drowsy-Related Events, Non-Drowsy Events, Drowsy-Related Baselines and Non-Drowsy Baselines by Time Since Last Break.

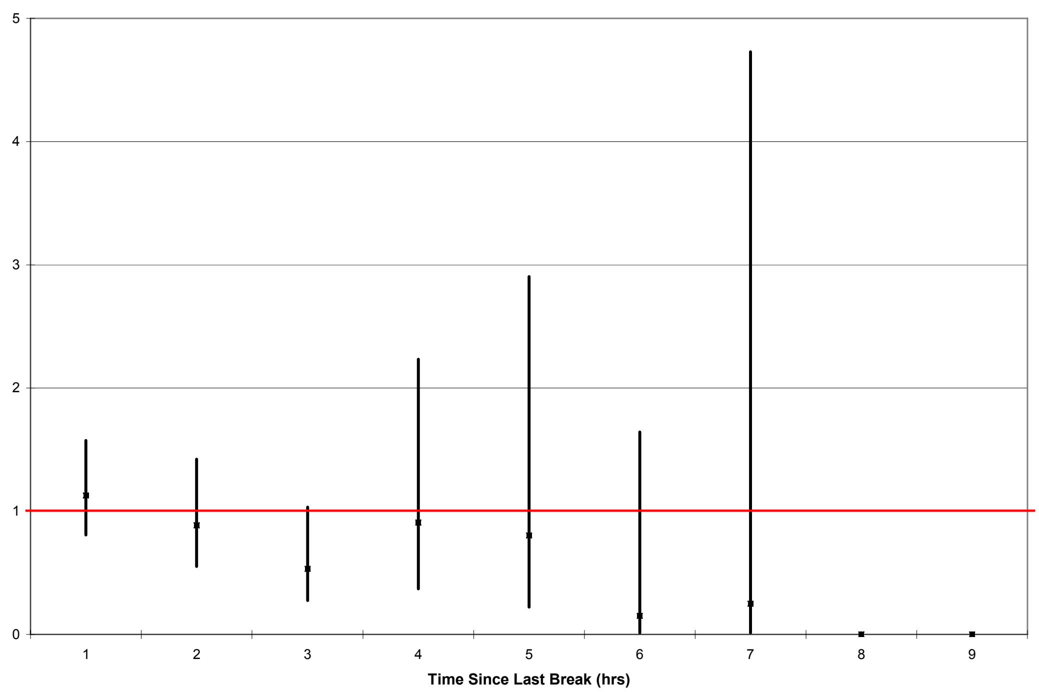

Figure 24. Odds Ratio of Drowsy-Related Events, Non-Drowsy Events, Drowsy-Related Baselines and Non-Drowsy Baselines by Time Since Last Break.

Cochran-Mantel-Haenszel Power Analysis

Because significance was not reached likely due to a small sample size, a post hoc power analysis was run using the Cochran-Mantel-Haenszel test in the statistical program SAS. The data were collapsed in each of the tables in APPENDIX D and the power analysis was run across the entire sample; the standard values for α (0.05) and β (0.8) were used (Keppel and Wickens, 2004); the actual odds ratio was set to 1.1. The results are shown below in Table 11. It can be seen that it was not possible to obtain the necessary sample sizes, from the FOT data, needed to produce statistically significant results.

Table 11. Results from Cochran-Mantel-Haenszel Power Analysis.

Variable	Actual Power	Actual N	N Necessary to Achieve 0.8
Time of Day*	.17	1375	13194
Day of Shift	.16	1231	14214
Day of Week	.17	1419	12322
Drive Hour	.17	1172	12329
Shift Hour	.15	955	12439
Time Since Last Break	.19	1359	12277

*Note: SAS was not able to compute an exact test with stratifications larger than 15; N is an estimation.

It is important to note that this analysis was not the primary goal of this data collection effort and was a secondary analysis. Therefore, it was not possible to perform a Power Analysis before the data collection had begun in order to ensure an adequate amount of data. If this analysis had been the primary goal of the data collection, a Power Analysis would have been performed before data collection began and the experimental design would have been developed so that enough data was collected to complete a sufficient analysis.

Research Question 2: Are drivers getting more sleep under the revised HOS regulations?

The data presented in this section comes from a published report in which the author of this research played an active role while conducting the analysis (Hanowski et al., June 2005). Although this sleep analysis is not the primary goal of this research, it does provide support for the subsequent section which contains one of the primary research questions. The following questions, asked by Hanowski et al. (2005), are relevant to this research:

1. What is the mean actigraph-assessed sleep quantity for drivers in the study?
2. Is there a difference in the amount of sleep received in the 24-hour period prior to being involved in a critical incident as compared to a driver's mean sleep quantity?

The results of the analysis are as follows. Question 1: What is the mean actigraph-assessed sleep quantity for drivers in the study? To answer this, data were used from 73 drivers who participated in the naturalistic study (as of May 1, 2005) and who had at least seven complete days of reliable data. The Action-W Version 2 software program was used to calculate sleep using the Cole-Kripke algorithm. To do this, the software scores each minute of actigraph data (across a 24-hour period) as either "sleep" or "wake". The "sleep" minutes are totaled and converted to hours.

Two methods were used to determine mean sleep quality. Method 1 included all full days (24 hours; 1440 minutes) that had less than 120 minutes where the watch was removed from the driver's wrist. Method 2 included complete weeks of data, containing at least seven consecutive days (Monday – Sunday). Method 2 could include more than one week of data for a driver but not less than one week. This method was used so that all drivers' mean sleep values included the same proportion of specific days (e.g., all participants have one Monday's worth of data for each week included). Table 12 provides a summary of the results of these two methods.

Table 12. Summary of results from question 1 analysis.

Analysis Method	Mean Hours of Sleep	Standard Deviation	Days of Data	Number of Drivers	Mean Age of Drivers	Age Range of Drivers
Method 1: All Data	6.15	1.36	4479	73	39.9	25 – 60
Method 2: Only Complete Weeks of Data	6.28	1.42	1736	62	40.1	25 – 60

Since Method 2 uses "day of week" as a within-subject variable, it is believed that this method provides more control and therefore these results will be used in making comparisons to the literature. Given that Mitler et al. (1997) found that "drivers averaged 5.18 hrs in bed per day and 4.78 hrs of electrophysiologically verified sleep per day over the five-day study (range, 3.83 hrs of sleep to 5.38 hrs of sleep), it can be seen that the results from the current analysis (mean hour of sleep = 6.28) suggest that drivers are getting more sleep under the 2004 HOS regulations.

Hanowski et al. (June 2005) lists two caveats to consider while making the above comparison:

a) Data from the current naturalistic study included night driving (for many cases almost all night driving) while the Mitler et al. (1997) study included four different controlled schedules: (1) steady day – 10 hours of driving beginning at approximately 9:00 am; (2) advancing night – 10 hours of driving beginning at 9:30 am the first day and 2 to 3 hours earlier each following day; (3) steady night – 13 hours of driving beginning at approximately 11:00 pm each day; and (4) delaying evening – 13 hours of driving beginning at 11:30 am on the first day and 1 hour later on each following day. One may argue that the closest of Mitler's conditions to use for a comparison to the current data is "advancing night", but seeing as the current data comes from a naturalistic study and driving schedules were not controlled for and since the mean sleep time for that condition (5.10 hours) is so close to the overall mean sleep time of all four conditions (5.18 hours), it seems appropriate to compare the current results to the overall mean sleep data reported by Mitler et al. (1997).

b) The second caveat assumes that the "hours in bed" value from Mitler et al. (1997) is comparable to the mean sleep hours from the Actigraph watch. However, the current study did not directly monitor drivers' time in bed as compared to the sleep time recorded from the actigraph watch. In addition, Mitler et al. (1997) only considered sleep for a five-day work week while the current study included all work and non-work days for each driver.

Several other comparisons are made in Hanowski et al. (2005), all of which suggest that drivers are getting more sleep under the 2004 HOS regulations than under past regulations.

Question 2 asked "Is there a difference in a driver's mean sleep quantity and the sleep quantity obtained prior to being involved in a critical incident?" To answer this, all critical incidents that occurred in the 10^{th} and 11^{th} hour of driving through May 1, 2005 were used. There were 58 critical incidents that involved 30 of the drivers. Each critical incident was determined to be either the participant driver at-fault or not at-fault; there were 43 critical incidents determined to be the participant driver at-fault from 27 of the participants.

The results are shown in Table 13 (N = the number of matched pairs in a given analysis). It can be seen that in the "Same 24-hour Interval" condition and the "Previous 24 hours" condition, the mean sleep quantity before an incident was significantly less than the overall sleep quantity for the same driver (for all three groupings). The "Previous 24-hour Interval" condition did not show significance. The same analysis was done on all the critical incidents (including participant driver not at-fault) and the same results were obtained. As a result, it can be said that two of the three methods used to divide the data answered "yes" to the question "Is there a difference in a driver's mean sleep quantity and the sleep quantity obtained prior to being involved in a critical incident?"

Table 13. Results of matched-pairs t-tests comparing mean sleep quantity before the critical incident to overall sleep quantity. Only participant driver at-fault incidents are included. Shaded rows indicate significance at $p < .05$.

Condition	N	Sleep Quantity Before Incident (hr)		Overall Sleep Quantity (hr)		T Statistic	P (T ≤ t) two-tailed
		Mean	SD	Mean	SD		
Previous 24-hr Interval vs. Overall Sleep Quantity	30	6.30	2.46	6.32	1.58	- 0.0701	0.9446
Previous 24-hr Interval vs. Overall Sleep Quantity (without Vacation and Outliers)	29	6.46	2.34	6.50	1.30	- 0.1000	0.9211
Previous 24-hr Interval vs. Chunks Sleep Quantity (without Vacation and Outliers)	28	6.40	2.36	6.73	1.67	- 0.7444	0.4631
Same 24-hr Interval vs. Overall Sleep Quantity	29	5.02	2.51	6.31	1.56	- 3.5422	0.0014
Same 24-hr Interval vs. Overall Sleep Quantity (without Vacation and Outliers)	28	5.15	2.46	6.49	1.28	- 3.5676	0.0014
Same 24-hr Interval vs. Chunks Sleep Quantity (without Vacation and Outliers)	27	5.31	2.36	6.62	1.67	- 3.4663	0.0018
Previous 24 hours vs. Overall Sleep Quantity	31	5.05	2.22	6.32	1.55	- 3.7744	0.0007
Previous 24 hours vs. Overall Sleep Quantity (without Vacation and Outliers)	30	5.16	2.16	6.49	1.28	- 3.8546	0.0006
Previous 24 hours vs. Chunks Sleep Quantity (without Vacation and Outliers)	29	5.25	2.15	6.70	1.65	- 3.9175	0.0005

Research Question 3: What are drivers' opinions of the revised HOS regulations?

One of the main goals of this research was to determine what drivers think of the revised HOS regulations. In order to do this each driver who participated in the naturalistic study was asked to answer a subjective questionnaire (APPENDIX A) at the end of his/her participation time. Since the questionnaire was added after the study had already begun, several of the early drivers were not able to complete the questionnaire but data were obtained from 78 of the drivers. The results of the questionnaire can be found below; all drivers who answered the questionnaire had driven under the revised HOS regulations.

Question 2: Do you think that it is important for professional drivers to follow HOS regulations (either old or revised)?

Table 14. Answers to question 2 of the subjective questionnaire.

Answer	Frequency	Percent
No	6	7.7%
Yes	72	92.3%
Total	78	100.0%

Question 3: How well do you think **you** follow the revised HOS regulations?

Table 15. Answers to question 3 of the subjective questionnaire.

Answer	Frequency	Percent
Very Well	46	59.0%
Somewhat Well	25	32.1%
Neither Well nor Poor	5	6.4%
Poor	1	1.3%
Very Poor	1	1.3%
Total	78	100.0%

Question 4: How well do you think **others** follow the revised HOS regulations?

Table 16. Answers to question 4 of the subjective questionnaire.

Answer	Frequency	Percent
Very Well	11	14.3%
Somewhat Well	40	51.9%
Neither Well nor Poor	15	19.5%
Poor	8	10.4%
Very Poor	3	3.9%
Total	77	100.0%

Question 5: How well do you think **your employer** makes drivers obey the revised HOS regulations?

Table 17. Answers to question 5 of the subjective questionnaire.

Answer	Frequency	Percent
Very Well	64	82.1%
Somewhat Well	14	17.9%
Neither Well nor Poor	0	0.0%
Poor	0	0.0%
Very Poor	0	0.0%
Total	78	100.0%

Question 6: How do you think your **amount** of sleep (number of hours of sleep per night) now compares to the amount of sleep that you got under the old HOS regulations? Why?

Table 18. Answers to question 6 of the subjective questionnaire.

Answer	Frequency	Percent
I got more sleep under the old HOS regulations	6	7.7%
I get the same amount of sleep under the revised HOS regulations as I did under the old HOS regulations	49	62.8%
I get more sleep under the revised HOS regulations	23	29.5%
Total	78	100.0%

Drivers who said they got more sleep under the old HOS regulations gave some of the following reasons. Four of the six drivers (66%) gave a why statement. For a complete list of responses see APPENDIX D.

- "You could stop and take naps and it would not go on your time per day."
- "10 hours is too much time off, it is too easy to get involved in other things (tv, games, conversation, etc.)."

Drivers who said they get the same amount of sleep under the revised HOS regulations as the old HOS regulations gave some of the following reasons. Thirty-four of the 49 drivers (69%) gave a why statement.

- "I still get in bed at the same time."
- "Too much sleep."
- "It seems like the older I get, the shorter my periods of sleep get."
- "Because I trained my body to go on 8 hours; hard to sleep longer."
- "Used to sleeping about 6-7 hours."
- "Schedule still dictates time available to sleep."

Drivers who said they get more sleep under the revised HOS regulations gave some of the following reasons. Nineteen of the 23 drivers (83%) gave a why statement.

- “Gives me a chance to slow down before I go to sleep.”
- “I feel more alert and less tired.”
- “More time off to sleep.”

<u>Question 7:</u> How do you think your **quality** of sleep (how well you sleep at night) now compares to the quality of sleep that you got under the old HOS regulations? Why?

Table 19. Answers to question 7 of the subjective questionnaire.

Answer	Frequency	Percent
I sleep better under the revised HOS regulations	17	21.8%
I sleep the same now as I did under the revised HOS regulations	55	70.5%
I slept better under the old HOS regulations	6	7.7%
Total	78	100.0%

Drivers who said they sleep better under the revised HOS regulations gave some of the following reasons. Twelve of the 17 drivers (71%) gave a why statement. For a complete list of answers see APPENDIX D.

- “Have more time to sleep.”
- “Work divided more evenly between day/night. Not as broken up as under old rules.”

Drivers who said they sleep the same now as they did under the old HOS regulations gave some of the following reasons. Thirty-one of the 55 drivers (56%) gave a why statement.

- “I still get in bed at the same time.”
- “My sleep quality I have found was subject to everyday life stress, not the amount of time I have to sleep.”
- “Nothing as far as work habits changed.”

Drivers who said they slept better under the old HOS regulations gave some of the following reasons. Five of the six (83%) gave a why statement.

- “Because 14 hour rule was not there.”
- “I was tired when I shut down.”

<u>Question 8:</u> Which do you like better? Why?

Table 20. Answers to question 8 of the subjective questionnaire.

Answer	Frequency	Percent
Old HOS regulations	25	33.8%
Revised HOS regulations	49	66.2%
Total	74	100.0%

Drivers who said they like the old HOS regulations better gave some of the following reasons. Twenty of the 25 drivers (80%) gave a why statement. For a complete list of answers see APPENDIX D.

- “10 hours off is too long.”
- “Old hours gave me more work hours to earn more money.”
- “I like the 34 hour restart but I don’t like 14 hour rule.”
- “When you take a break whether its off-duty or in the sleeper, it shouldn't be used against 14 hour rule.”

Drivers who said they like the revised HOS regulations better gave some of the following reasons. Thirty-nine of the 49 drivers (80%) gave a why statement.

- “11 hours drive time and 34 hour restart.”
- “The amount of hours you get now to drive. Helps you plan your trip easier.”
- “Can get more sleep. Can reset 70 hours.”
- “You can pick up 70 hours after having 2 days off, easy to keep and track logs.”

Finally, drivers were asked what they would change if they could change anything about the revised HOS regulations (question 9). The most frequent answers are listed below. A complete list of answers can be found in APPENDIX D.

Table 21. Answers to question 9 of the subjective questionnaire.

Answer	Frequency	Percent
No change	29	33.7%
Change 14 hour rule	14	16.3%
Decrease break time	10	11.6%
Other	10	11.6%
Stop clock with breaks	8	9.3%
Increase driving time	3	3.5%
Go back to old HOS regulations	2	2.3%
Change 34-hour restart	2	2.3%
Go back to old HOS regulations but keep 34-hour restart	2	2.3%
Increase total work week time	1	1.2%
Hold companies more responsible	1	1.2%
Have an only truck lane	1	1.2%
Install GPS system on trucks	1	1.2%
Install an on-board logging system on trucks	1	1.2%
Have more enforcement	1	1.2%

CHAPTER 5: CONCLUSIONS

Summary of Findings

There were two main goals to this research: 1) gain a better understanding of the time-related occurrences of drowsy-related critical incidents (i.e., crashes, near-crashes and crash-relevant conflicts), and 2) obtain drivers' opinions of the revised HOS regulations. A summary of findings from each is provided below.

Time-related occurrences of drowsy-related critical incidents

One significant finding was that there were more drowsy-related critical incidents between 2:00 pm and 2:59 pm. This result was expected since there is a circadian rhythm low between the hours of 2:00 pm and 4:00 pm (Stutts et al., 1999). It was also expected that there would be an increase of drowsy-related critical incidents during the night hours but that was not found in the results. The time periods between 11:00 pm and 11:59 pm (OR = 4.02; UCL = 17.51, LCL = 0.92) and 12:00 am and 12:59 am (OR = 3.08; UCL = 12.34, LCL = 0.77) were close to producing significant odds ratios when compared to the other time blocks. There are several possible explanations with regard to the lack of significant odds ratios for the night hours. First, there was a lack of exposure for some drivers. Although the FOT aimed to recruit drivers who did a large amount of night-time driving, once the data were collected it was apparent that many drivers spent the majority of their time driving during the day. Therefore, these drivers did not have the chance to have drowsy-related critical incidents at night. A second explanation is that drivers are often on interstates with very little surrounding traffic during the night hours. The lack of other vehicles on the road may reduce the instance of a critical incident occurring at all. A future analysis might involve comparing single vehicle critical incidents to multiple vehicle critical incidents to see if there is a pattern in their occurrence.

The lack of significant odds ratios was likely due to a small sample size. The variables used in this analysis (e.g., time of day, drive time, shift time, etc.) were broken into many smaller 'bins' into which each critical incident was placed; that resulted in many bins which contained only one or two critical incidents. There are two ways to remedy this for future research: 1) increase the overall sample size by collecting additional data and adding more critical incidents, or 2) collapse the bins so that there are more critical incidents in each bin. According to the Cochran-Mantel-Haenszel Power Analysis, approximately 1400 critical incidents would be needed to produce significant results using the current analysis method. It is not possible to obtain that many critical incidents unless either the methodology for determining critical incidents is improved (see the Research Limitations section later in this chapter) or additional naturalistic data is collected.

Revised Hours-of-Service Regulations

Given that the first major change was made to the HOS regulations in 2004, since their introduction in 1938, it was beneficial to obtain opinions of the revisions from drivers who had driven under both sets of regulations. This was done by asking 78 of the drivers who participated in the FOT to answer a short, subjective questionnaire regarding the revised HOS regulations. In addition, each driver wore an actigraph watch during their participation time in order to collect data on their sleep patterns under the revised HOS regulations.

Subjective Data

When developing and implementing policy such as the HOS regulations, it is important to consider the opinions of those who will follow the policy in order to increase compliance. Although researchers may believe that scientific results can lead to the correct development of HOS regulations, if the driver does not agree with the regulations, he/she will find ways to break the rules. Often drivers feel that it is beyond their control because tight company deadlines force them to exceed driving time limitations. Based on the data collected during this research, recommendations are suggested (later in this chapter) for future HOS revisions.

Sleep Data

Sleep data were also considered from a recent analysis performed at VTTI using actigraph data collected during the FOT. Results from this analysis show that, on average, drivers are getting more sleep under the revised HOS regulations when compared to the old HOS regulations. These results are encouraging given that the revised HOS regulations require a two-hour longer break between shifts.

Table 22. Average sleep quantity under the old HOS regulations vs. the revised HOS regulations

	Old HOS regulations – 8 hours off duty	Revised HOS regulations – 10 hours off duty
Average sleep	5.18 hours*	6.26 hours

*Source: Mitler et al., 1997

Although nearly twelve percent of the participants stated that they would like the break time decreased (see Question 9 under Research Question 3 in the Results chapter), the actigraph data shows that drivers appear to be getting more sleep and that the longer break time may be beneficial to some. Future research may investigate this issue further by allowing drivers to see their actigraph data. If drivers are made aware that the extra off-duty time is increasing their daily sleep, they may be more accepting of the revised HOS regulations and more willing to comply.

The Sociotechnical System in the Trucking Industry

This research resulted in several interesting findings. The findings will be incorporated into recommendations that can be used to improve safety for CMV (tractor-trailer) drivers. In order to do this the Sociotechnical Systems (STS) model will be used to relate the findings into recommendations. The recommendations listed below are the ideas of the author of this research and are based on the literature review and the results from this study.

The STS model "views organizations as transformative agencies; they transform inputs into outputs. Sociotechnical systems bring three elements to bear on this process: a technological subsystem, personnel subsystem, and work system design consisting of an organizational structure and processes. These three elements interact with one another and the external environment on which the organization depends for its survival and success" (Hendrick and Kleiner, 2001; p.22). The STS model is depicted in Figure 25 and each subsystem is described in more detail below.

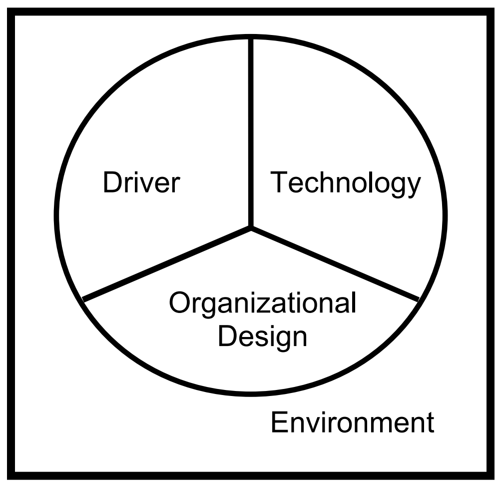

Figure 25. The Sociotechnical Systems Model.

Table 23. Description of the Four Sociotechnical Systems Subsystems.

Subsystem	Description	Examples in the Trucking Industry
Technology	Technology, tools, work rules, information, machinery and equipment used to turn inputs into outputs (Kleiner, 1999b).	• Trucks • Storage facilities • Distribution/warehouse center • Buildings and equipment (e.g., computers) (Hanowski, 1998)
Personnel	The characteristics of the personnel working at an organization (i.e., degree of skills/training required, cognitive complexity of work performed, personal factors) (Hanowski, 1998).	• Sleep behavior • Off-duty activities • Eating/exercise habits • Medications/caffeine use • Medical conditions (e.g., sleep apnea)
Organizational Design	The structure of an organization (Kleiner, 1996), including who is managed, what is managed, and what is used to manage (Kurstedt, 1994). As cited in Hanowski, 1998.	• Company policies, rules, and regulations
Environment	External forces such as economics, competition, politics, and legalities (Hanowski, 1998).	• Federal policies, rules, and regulations (e.g., Hours-of-Service regulations)

One benefit of the STS model is that it identifies interacting issues that may be overlooked. That is, it is not only the responsibility of the driver, but also the trucking company and the consignees to help the driver follow the HOS regulations and to avoid driving drowsy. The STS model is viewed as an ‘open system’, that is “work systems have permeable boundaries exposed to the environment in which they exist (political, economic, social, etc.). These environments thus enter or permeate the organization along with the inputs to be transformed” (Hendrick and Kleiner, 2001; p.24). Another important concept of the STS model is ‘joint optimization’. The goal of joint optimization is to optimally design both the Personnel subsystem and the Technological subsystem so that they work together. This concept will explained in more detail later in this chapter. The following recommendations are discussed from the findings of this research and using the STS model as a structure.

Recommendations for the HOS Regulations Based on Subjective Data

Specific Recommendations for Future HOS Regulations Revisions

When considering the STS model described above, the HOS regulations may fall under the environmental subsystem; a federal policy applied to all drivers. During this research, drivers were asked 'If you could change anything about the revised hours-of-service regulations, what would it be?' Based on the answers given, the following three recommendations are made for future HOS regulations revisions: 1) change the 14-hour rule, 2) maintain the 10-hour break rule, and 3) maintain the 34-hour restart rule.

Change the 14-hour rule.

Sixteen percent of drivers stated that they would like the 14-hour rule changed. This was the second most frequent response to this question (the most frequent response was 'No change'). The revised HOS regulations require drivers to count all breaks (i.e., non-driving) towards a total of 14 hours that can be worked in a 24-hour period. It is recommended that drivers continue to be limited to 11 hours of driving, but be allowed to take breaks or naps throughout the day as necessary and not have them count towards the 14 hours of on-duty time. Macchi et al. (1997) simulated a night shift with professional truck drivers and found that a 3-hour nap "alleviated the combined effects of increasing sleep pressure and of the circadian nadir in alertness and performance rhythms", therefore, naps may be very beneficial to the safety of the driver. Forcing drivers to count naps as part of their workday may actually decrease the chances of a driver taking a nap since drivers are paid by the mile (and not by the hour) and often want to drive as many miles as possible.

Maintain the 10-hour break rule.

Although nearly twelve percent of the participants stated they would like to have the 10-hour break rule decreased, the data collected in this research show that drivers are getting the same amount of sleep or more sleep under the revised HOS regulations. Twenty-two percent of drivers state that they get a better quality sleep under the revised HOS regulations, and thirty percent of drivers state that they get more sleep under the revised HOS regulations. Table 24 shows the mean sleep time (in hours) for each answer, it can be seen that the longest amount of sleep is obtained by the group that gave a self-report of getting more sleep under the revised HOS regulations. Note that mean actigraph data were not available for each of the drivers who answered the question. In addition, actigraph data were not available for drivers under the old HOS regulations and perception data (e.g., how many hours a night drivers thought they were sleeping) were not available, so direct comparisons using the subjective questionnaire could not be made.

Table 24. Mean Sleep Time (from actigraph watch) for each Answer to Question 6.

Answers to Question 6	Mean Sleep	SD	N
I got more sleep under the old HOS regulations	6.29	1.05	4
I get the same amount of sleep under the revised HOS regulations as I did under the old HOS regulations	6.24	1.31	32
I get more sleep under the revised HOS regulations	6.69	1.18	18

Additionally, the actigraph data shows that drivers appear to be getting an additional hour of sleep under the revised HOS regulations as compared to the old HOS regulations (Hanowski et al., 2005; Mitler et al., 1997). A driver's sleep pattern may fall under the Personnel subsystem of the STS model, while the HOS regulations would fall under the Environmental subsystem. This helps to show how the environment in which the driver works (the driver is required to take 10 hours off duty) has a positive effect on the driver's sleep.

Maintain the 34-hour restart rule.

When asked why drivers preferred the revised HOS regulations (Question 8) to the old HOS regulations, nearly twenty-nine percent of drivers stated that they liked the 34-hour restart rule. When drivers were asked what they would change about the revised HOS regulations, only two percent of drivers stated they would change the 34-hour restart rule. The 34-hour restart rule is beneficial to drivers because it allows them an extended period of time to catch up on sleep and to repair the sleep debt that may have accumulated during the work week. In addition, it allows drivers to restart their 70 hour work week.

Recommendations for Clients and Truck Companies

In addition to the above changes to the HOS regulations, drivers also suggested that the following would make it easier to obey the HOS regulations. The following recommendations are made specifically for tractor-trailer drivers.

Time Between Deliveries and Loading/Unloading Time.

Drivers often feel that they do not have enough time to get to their next delivery location and that it takes too long to load or unload their trailer once they do get to the delivery location. The meeting times are often set up by the trucking companies and may not take into account travel delays due to traffic accidents, inclement weather, vehicle problems or other delays. If delays do occur, drivers may feel compelled to break the HOS regulations or drive while drowsy (by not taking breaks) in order to get to their next delivery on time. In several focus groups conducted by the FHWA (December, 1998), drivers stated that they felt "economic pressures" were a major contributing factor when it came to dispatchers setting drivers schedules. Dispatchers should be considerate to the fact that there may be negative consequences to drivers (and companies) for violating the HOS regulations. Because of this, dispatchers should allow additional time for drivers to get to his/her next appointment.

Also, drivers often wait for hours at the consignee for their trailer to be loaded or unloaded. If this wait is longer than anticipated, the drivers' schedule may be affected, possibly causing them to be late for the next appointment. Additionally, most drivers are paid by the mile, not by the hour, so drivers are not making any money during this waiting period and may feel pressure to drive additional miles to make up for the lost pay. This may also lead drivers to feel compelled to continue driving beyond their 11 hours of driving or while drowsy. It would benefit the drivers if the consignee were aware of the consequences for the drivers (i.e., having their license revoked for violating the HOS regulations and driving drowsy). One possible change would be for consignee to have additional loading/unloading staff so that each trailer can be loaded or unloaded more efficiently or so that multiple trailers can be loaded or unloaded at the same time. Additionally, fleet companies may impose a "fine" to consignees who do not load or unload within a pre-set time window.

The STS model may also be used to help relate the above recommendations concerning company dispatchers and consignees. The truck drivers themselves would fall under the Personnel subsystem while the dispatchers (those who set up delivery times for the drivers) may fall under the Organizational subsystem as part of the company management. The consignee may fall under the Environmental subsystem as someone outside of the trucking company but still affecting the way that the driver performs his/her job. As previously mentioned, the bottom line is that dispatchers and consignees, along with the driver, have to take responsibility for following the HOS regulations and ensuring that the driver does not drive when drowsy.

Recommendations to Prevent Drowsy Driving in Commercial Vehicle Drivers

The following recommendations are made to help reduce drowsiness in CMV (tractor-trailer drivers) that in turn may make the highways safer for all drivers.

Provide a Driver Fatigue Monitor

One concept that researchers have found over time is that drivers are not usually aware of when they become drowsy, and they often underestimate the level of their drowsiness (Wierwille, et al., 2003). It would benefit CMV drivers to have a reliable device that monitors their drowsiness level and alerts the driver as to when they are too drowsy to continue driving safely. A similar device was tested by VTTI as the main goal of this data collection effort, but was found to have limitations. For example, the current driver fatigue monitor did not work reliably for drivers who wore glasses and did not work well in high ambient conditions (i.e., daylight). In addition, the system monitored the driver's eyes to assess closure, but preliminary checks of the raw data appear to indicate that the driver fatigue monitor was not sensitive to distinguish head-turns from eye-closures (i.e., resulting in 'false positive' alarms). A modified device could improve upon these limitations and provide a balance of reliable detection and minimal false alarms.

Road Signs and Billboards

Also stated in Chapter Two, CMV drivers often spend many hours on highways and interstates with little scenery and this may contribute to drowsiness. Through talking with CMV drivers while collecting data for studies at VTTI, drivers have mentioned the monotony of driving on long, open highways, this leads to the suggestion of placing additional advertising billboards along the road to give drivers something to look at. In addition, signs encouraging drivers to pull over and take a quick nap or get a cup of coffee could also be added. The latter may be placed near truck stops so that drivers may quickly exit the road to engage in these behaviors. Adding such road signs may help drivers combat boredom and drowsiness while driving on long, monotonous stretches of roadway.

One concern with this approach is the potential to distract drivers by taking their eyes off the roadway to look at road signs. Lee, Olsen, and Dehart (2004) found that there is not a measurable difference in speed maintenance and lane deviations in the presence of billboards, when compared to baseline data. Although the benefits to reducing drowsiness from the presence of billboards are unknown, research has found that billboards are not likely to cause an additional distraction to the driver.

Test for Sleep Disorders

Another problem among CMV drivers is sleep disorders such as sleep apnea. Sleep apnea occurs when a person stops breathing during their sleep period. Multiple occurrences of this may decrease the person's quality of sleep at night, causing the driver to become drowsier during the day. Pack, Dinges, and Maislin (2001) found that mild sleep apnea (5 – 15 episodes/hour) occurs in 17.6% of CMV drivers, moderate sleep apnea (15 – 30 episodes/hour) occurs in 5.8% of CMV drivers and severe sleep apnea (30 or more episodes/hour) occurs in 4.7% of CMV drivers. In addition, Pack et al. (2001) found that sleep apnea most commonly occurs in overweight, older men. According to FMCSA, drivers are required to receive, and pass, a bi-annual physical exam. During the exam, drivers are asked to give a self-report of any sleep problems, including 'pauses in breathing while sleeping'; if the driver reports a sleep problem, the doctor is instructed to refer the driver to a specialist. Drivers may not be aware of such pauses in breathing and therefore may not report this as a problem. It may benefit the trucking industry to test drivers specifically for such sleep disorders during the physical exam (or during an additional exam) prior to sending drivers out on the road. If a driver tests positive for a disorder the company may be able to assist drivers in treatment or schedule drivers to work during times when the disorder is least likely to affect them (i.e., during the day).

Sleep Monitoring Device

Another suggestion would be to provide drivers with feedback as to how many hours of sleep are received, in addition to the quality of sleep that is received. This can be done by having drivers wear sleep-monitoring devices on their wrist similar to a wristwatch. Such a device may monitor the drivers' activity levels and let the driver know what time they fell asleep (very low activity level), what time they woke up (resume high activity level) and how well they slept throughout the night. For instance, drivers who have restless sleep would be able to see this in the data (Figure 26 and Figure 27) and may be able to make adjustments to their sleeping habits such as sleeping on a different mattress or adjusting the climate in the bedroom.

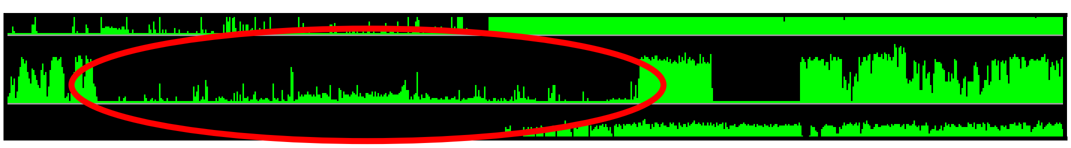

Figure 26. Example of sleep data from a driver with restless sleep (low quality of sleep).

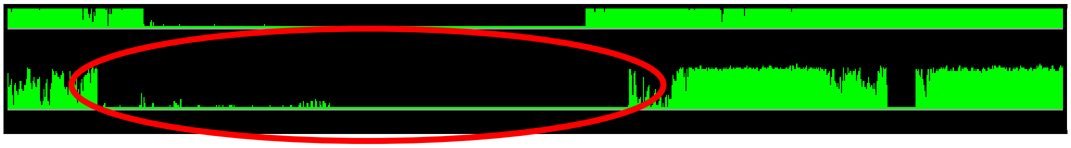

Figure 27. Example of sleep data from a driver with stationary sleep (high quality of sleep).

These adjustments may provide the driver with a more comfortable sleeping environment, which may in turn help them sleep better. Once drivers are able to obtain a good night's sleep, they may be less likely to become drowsy during the day.

Reduce High-Risk Drivers

Another issue to consider is drivers who are at a higher risk to have drowsy-related crashes. Research shows that younger males are at a higher risk for these types of crashes (Knipling and Wang, 1994). It may be beneficial to the trucking industry to consider this while hiring new drivers. For example, companies should provide additional training to potentially high-risk drivers or schedule these drivers during the day so they limit the amount of time that they are on the road during the night when drivers are drowsier. Reducing the number of high-risk drivers on the road may help to make the roads safer for everyone.

Provide Drowsiness Prevention Training

Finally, as previously stated drivers often do not know how drowsy they are. It may help drivers realize their drowsiness levels by teaching them the signs of drowsiness so that they are aware of when they need to pull over and take a break. Trucking companies could do this by providing additional training programs or workshops to drivers so that they understand the signs of drowsiness (e.g., repeated yawning, wandering thoughts, and missing traffic signs or exits) and how to prevent it. In addition, drivers may be trained on behavior-based safety, which "provides tools and methods employees can use to take control of their own safety performance" (Geller, 2001; p.87). One example of this may be to train drivers on potential drowsy-related behaviors of other CMV drivers on the road such as a high number of lane deviations. This would allow the driver to become more aware of his/her surroundings in addition to possibly reducing the behavior by letting the other driver know that they are engaging in risky behavior (e.g., contacting them by CB radio). Drivers should also be aware of the fact that certain medications and any type of alcohol consumption may contribute to drowsiness. Furthermore, drivers should be provided with the statistics of drowsy driving crashes so that they are aware of the consequences to themselves and other drivers if they continue to drive while drowsy. Educating drivers on all aspects of drowsiness may help them to make better decisions relating to their sleep habits.

Relating the STS Model to Drowsiness Prevention Recommendations

Each of the above recommendations can be placed into one of the four STS model subsystems. For example, providing the driver with a Driver Fatigue Monitor and a sleep monitoring device (such as an actigraph watch) would fall under the Technology subsystem as a tool to assist the driver in performing their job. The recommendations relating to testing for sleep disorders and reducing high-risk drivers would fall under the Personnel subsystem because those are characteristics of the driver. The recommendation suggesting additional drowsiness prevention training would fall under the Organizational subsystem because it is related to company policies and regulations. In addition the recommendation to add additional road signs would fall under the Environmental subsystem as something outside of the trucking industry but possibly impacting the driver (Personnel subsystem). Again, the ‘open systems’ approach to this model helps to show that it is not only the responsibility of the driver to engage in behaviors to prevent drowsy driving but rather the responsibility of all components in the trucking industry to help prevent drowsy driving.

Finally, the current STS model also requires joint optimization to ensure that each subsystem receives the same amount of focus. For example, if a given fleet company wants to adopt a program to help reduce drowsiness in tractor-trailer drivers, the following modifications should be taken into consideration under each of the subsystems.

Under the Organizational subsystem, the company could provide drowsiness prevention training to educate drivers and assist them in identifying signs of potential drowsiness. Also, prior to letting drivers on the road, the company could test for disorders that might affect their driving if not treated properly (e.g., sleep apnea,) as well as create programs that try to identify and reduce high-risk drivers and present drivers with possible risk and drowsiness countermeasures. For example, a driver that has a sleep disorder might need policies in place that support adjusting their driving schedule to allow them driving periods when they are less likely to become drowsy. These modifications would optimize the relationship between the Personnel and Organizational subsystems by not only focusing on the driver but also redefining what the organization itself would strive for.

In addition, to create a synergetic approach across Personnel, Organization, and Technology subsystems, the company could also provide drivers with technology that may help them overcome their limitations (e.g., identify when they start getting drowsy and when they need to stop driving) by providing a tool that may assist them in this process (e.g., a Driver Fatigue Monitor). It is important to emphasize that in order for each subsystem to work properly, the company needs to be able to enforce the policies to ensure that drivers engage in the desired behavior (e.g., if the driver does become drowsy or receives an alert from the Driver Fatigue Monitor they would be encouraged to engage in a countermeasure such as stopping for a cup of coffee or pulling over to take a break). Because of this, there also needs to be a link between the Organizational and Technological subsystems in order for the subsystems to work together. If drivers do not follow the policies set in place for their benefit by the company (e.g., testing for sleep disorders as described above), the remaining subsystem (Technology) needs to be able to close the loop between the Organizational and Personnel subsystems. To do this, the Technological subsystem (e.g., Driver Fatigue Monitor) should be able to provide information to the company in order for them to modify the behaviors that might still need to be corrected, in addition to just providing instantaneous feedback about drowsiness. This synergetic approach will ensure that drivers would be more likely to follow company policy and use the tools provided in the future.

Preventing Drowsiness in Other Industries

It is interesting to note how other industries attempt to prevent drowsiness. For example, Army pilots have been given various stimulants (Provigil and Dexedrine) to help reduce the effects of drowsiness. Caldwell (2005) found that both drugs were able to sustain "the alertness and performance of sleep-deprived" normals" (p.35) but produced some unwanted side effects such as nausea and vertigo.

Drowsiness research has also been conducted in the railroad industry. The North American Rail Alertness Partnership strategic plan, developed in 1997, has come up with several countermeasures to help prevent drowsiness in railway workers. These countermeasures include: 1) education and training, 2) employee scheduling practices, 3) emergency response requirements, 4) alertness strategies, 5) evaluation of policies and procedures, 6) adequate rest environments, 7) work environment and 8) implementation strategies (Coplen and Sussman, 2000). It is also interesting to note that railway workers face many of the same issues as CMV drivers when it comes to fatigue such as extensive night work, irregular schedules and extended work periods with few or no days off (Coplen and Sussman, 2000).

Another industry in which drowsiness is a concern is the health care industry. Similar to the trucking industry, health care providers often work long, irregular shifts. Joffe (2006) describes several countermeasures that emergency pediatric workers may use to help combat drowsiness. First, workers should make sure that their sleep environment is conducive to a good nights sleep such that the room is kept as dark as possible and noise levels are kept at a minimum. Also, caffeine and alcohol should be avoided prior to going to sleep. Health care providers often have to continue working while drowsy and may be encouraged to consume caffeine or may be prescribed Provigil a 'nonstimulant alertness agent' to help reduce some of the effects of fatigue.

Limitations and Future Research

Triggers

The methodology used to create the triggers in the FOT data may have been a limiting factor. At the time that the triggers were developed, there were not any publications listing values to be used while creating triggers. As such, the trigger values were obtained through trial-and-error testing but were not validated through statistical analysis. Because of this, it is possible that there were a number of missed valid events in the data. For example, the hard braking trigger (longitudinal deceleration) was set at ≤ -0.35g (that is, the driver had to hit the brakes at -0.35g or harder). There may have been additional valid events (e.g., the driver had to perform an evasive maneuver, hard braking, to avoid a potential traffic conflict) that occurred when the longitudinal acceleration value did not reach the trigger threshold (e.g., longitudinal deceleration = -0.30g). A current research project at VTTI is being conducted to find the optimum trigger values to reduce the number of missed events.

Drive History Software

As stated in Chapter 4, there are several caveats for the drive history software. The primary limitation is the lack of off-duty data from the driver. Because of this, it is not possible to know if the driver was performing non-driving tasks while on-duty, or if he/she was off-duty. This may impact the results from the 'shift hour' variable. Also, there are times in which the DAS did not collect the data properly (i.e., there may be missing or bad files in the middle of a driver's shift). It is possible that some of these missing time periods may have been considered off-duty or break time, when they in fact should have been driving time. In addition, if the face camera was out on any given file, that file was removed because it could not be determined with one hundred percent confidence that the driver was the participant driver. Each of these factors could have impacted several of the variables (e.g., shift hour, drive hour, and time since last break), however it is believed that the impact would be small and would not have affected the final results of this study. Future research would benefit greatly from off-duty data from the drivers as well as an improved DAS to reduce the number of missing files or camera outages.

ORD

ORD is a difficult measure in that it is a subjective measure and is the opinion of the analyst. In order to remove variability among multiple analysts, a single, trained analyst obtained all ORD measures but the data may still be biased based on how that analyst viewed drowsiness. In addition, the trained analyst was the author of this research which may have unintentionally biased the data; future use of ORD will use trained analysts who do not know what the ORD measures will be used for. Wierwille and Ellsworth (1994) used the mean scores from three different analysts to validate the measure of ORD; use of this method but will be taken into consideration in future research projects using ORD.

When discussing ORD and drowsiness, another limitation is that ORD is a direct measure of drowsiness, that is the analyst has to view signs of drowsiness (e.g., droopy eyes, yawning, etc.) in order to provide a rating. There may be other mental states of drowsiness that could affect the driver's ability to drive safely, which could not be measured by ORD.

Subjective Data

Although the questionnaire provided some very useful information regarding the revised HOS regulations, it would be beneficial to modify the procedure for administering the questionnaire. The drivers were given the questionnaire with several other questionnaires (regarding the FOT) at the same time, giving them a lot of paperwork to do at one time. The HOS questionnaire should be administered by itself and drivers should be required to fill out the 'why' section of each question as this provides very important information about their opinions of the revised HOS regulations.

Final Thoughts

In conclusion, drivers are more likely to have a drowsy-related critical incident between 2:00 pm and 2:59 pm. There was not enough data to draw significant results regarding drowsy-related critical incidents and the remaining variables.

Overall, drivers appear to be satisfied with the revised HOS regulations. The majority of drivers prefer the revised HOS regulations over the old HOS regulations. In addition, drivers appear to be obtaining more sleep under the revised HOS regulations when compared to the old HOS regulations. Both of these findings may indicate that the changes made to the revised HOS have been beneficial and have had a positive influence on the CMV industry.

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APPENDIX A: HOS QUESTIONNAIRE

Hours-of-Service Regulations Questionnaire

Please take a few minutes to fill out this questionnaire regarding the revised hours-of-service regulations (effective January 4, 2004). All information is strictly confidential and is for research purposes only.

THIS INFORMATION WILL NOT BE SHARED WITH YOUR EMPLOYER. Thank you for your participation.

Old Hours-of-Service Regulations	Revised Hours-of-Service Regulations
CMV driver may drive 10 hours after 8 hours off-duty.	CMV driver may drive 11 hours after 10 hours off-duty.
CMV driver may not drive after 15 hours on-duty, following 8 hours off-duty.	CMV driver may not drive beyond the 14th hour after coming on-duty, following 10 hours off-duty.
CMV driver may not drive after 60/70 hours on-duty in 7/8 consecutive days.	CMV driver may not drive after 60/70 hours on-duty in 7/8 consecutive days. ➢ A driver may restart a 7/8 consecutive day period after taking 34 or more consecutive hours off-duty.

Please put a check mark (✓) next to <u>ONE</u> answer for each question:

1. Have you ever driven under the revised hours-of-service regulations that are listed above?
   ☐ No ☐ Yes

   If your answer is yes, please continue with the rest of the questionnaire.
   If your answer is no, please return the questionnaire to the researcher. Thank you for your time.

2. Do you think that it is important for professional drivers to follow hours-of-service regulations? (either old or revised)
   ☐ No ☐ Yes

3. How well do you think **you** follow the revised hours-of-service regulations (since January 4, 2004)?
   ☐ Very Well
   ☐ Somewhat Well
   ☐ Neither Well nor Poor

☐ Poor
☐ Very Poor

4. How well do you think **others** follow the revised hours-of-service regulations (since January 4, 2004)?
   ☐ Very Well
   ☐ Somewhat Well
   ☐ Neither Well nor Poor
   ☐ Poor
   ☐ Very Poor

5. How well do you think **your employer** makes drivers obey the revised hours-of-service regulations (since January 4, 2004)?
   ☐ Very Well
   ☐ Somewhat Well
   ☐ Neither Well nor Poor
   ☐ Poor
   ☐ Very Poor

6. How do you think your **amount** of sleep (number of hours of sleep per night) now compares to the amount of sleep that you got under the old hours-of-service regulations (before January 4, 2004)?
   ☐ I got more sleep under the old hours-of-service regulations (before January 4, 2004)
   ☐ I get the same amount of sleep under the revised hours-of-service regulations as I did under the old hours-of-service regulations
   ☐ I get more sleep under the revised hours-of-service regulations (after January 4, 2004)
   Why? ____

   ____

7. How do you think your **quality** of sleep (how well you sleep at night) now compares to the quality of sleep that you got under the old hours-of-service regulations (before January 4, 2004)?
   ☐ I sleep better under the revised hours-of-service regulations (after January 4, 2004)
   ☐ I sleep the same now as I did under the old hours-of-service regulations
   ☐ I slept better under the old hours-of-service regulations (before January 4, 2004)
   Why? ____

   ____

8. Which do you like better:
   - ☐ Old hours-of-service regulations (before January 4, 2004)
   - ☐ Revised hours-of-service regulations (after January 4, 2004)

   Why? ____

   ____

9. If you could change anything about the revised hours-of-service regulations, what would it be? (Please take a minute to answer this question…this is a chance to voice your opinion on this important issue.)

   ____

   ____

   ____

   ____

   ____

   ____

THANK YOU FOR YOUR PARTICIPATION!

APPENDIX B: IRB FORM

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Request for Approval of Research Involving Human Subjects:
DROWSY DRIVER WARNING SYSTEM (DDWS) FIELD OPERATIONAL TEST (FOT) TASK 18: DDWS AND DATA ACQUISITION SYSTEM (DAS) ON-ROAD DATA COLLECTION

Submitted by:
Dr. Richard Hanowski
Principal Investigator, Truck and Bus Safety Group Leader
Dr. Ron Knipling
Senior Research Scientist
Akiko Nakata
Truck and Bus Safety Group Senior Research Associate
Virginia Tech Transportation Institute
for Project# NRD-01-2-07424, Task Order #14

1. PROJECT BACKGROUND AND JUSTIFICATION

Project Overview
Transportation operator drowsiness/fatigue is an important safety concern of the U.S. Department of Transportation. The National Highway Traffic Safety Administration (NHTSA) and the Federal Motor Carrier Safety Administration (FMCSA) have major programs to educate the public on the risks of driving while drowsy and to develop and demonstrate a vehicle-based countermeasure to driver drowsiness.

Commercial motor vehicles – long-haul trucks – are being used as the test bed for the development of a vehicle-based countermeasure to driver drowsiness. Drowsiness is an issue of special concern within commercial motor vehicle (CMV) transportation. CMV drivers may drive up to 10 hours[1] continuously before taking a break, often drive at night, and sometimes have irregular and unpredictable work schedules. Much of their mileage is compiled during long trips on interstate and other divided highways. Because of their greater mileage exposure and other factors, CMV drivers' risk of being involved in a fatigue-related crash is far greater than that of non-commercial drivers. Drowsiness is a primary cause of CMV crashes: in particular, single-vehicle crashes resulting in serious injury or death to CMV drivers. In addition, laboratory, simulator, and instrumented vehicle studies have shown that drowsiness contributes to driver inattention and decision errors while driving. Although the number of crashes related to CMV driver drowsiness is difficult to quantify, it is regarded as a major factor in CMV driving safety.

[1] On January 4th, 2004, this will increase to 11 hours.

The principal technology identified by NHTSA/FMCSA/FHWA ITS Joint Program Office (FHWA ITS JPO) as a countermeasure to driver drowsiness/fatigue is a vehicle-based Drowsy Driver Warning System (DDWS). A DDWS detects physiological indications of driver drowsiness/fatigue (i.e., slow-eye closures) and provides alerting feedback to drivers regarding their drowsy status. Drivers can then use this information to seek rest or to take other corrective steps to increase alertness (e.g., drink a cup of coffee). If such a system is successfully implemented, it may have a substantial impact on reducing drowsiness-related truck crashes.

NHTSA/FMCSA/FHWA ITS JPO has awarded a contract to the Virginia Tech Transportation Institute (VTTI) to conduct a Field Operational Test (FOT) of a DDWS. The DDWS being tested is called the Driver Fatigue Monitor (DFM). The DFM was developed by researchers at the Carnegie Melon University and has been the focus of several U.S. DOT sponsored efforts, including previous research conducted by VTTI (Wierwille et al., 2002).

The objective of this FOT is to collect data that can be used to evaluate the effectiveness and operational capabilities, limitations, and characteristics of the DDWS. More specifically, there are seven goals in this FOT:

1. Achieve a detailed understanding of DDWS safety benefits.
2. Characterize DDWS performance and capability.
3. Assess the driver acceptance of the device in its current state.
4. Assess the fleet management acceptance of the device in its current state.
5. Assess the deployment prospects of the DDWS.
6. Develop recommendations for DDWS design changes directed at optimizing safety benefits and increasing driver and fleet management acceptance.
7. Assess how a DDWS should fit within a comprehensive fatigue management program.

To perform these analyses, there are four general requirements associated with meeting the FOT objectives. First, the evaluation will occur in a naturalistic driving environment, and data must be collected from actual truck drivers. Second, the subject population included in the FOT will be representative of the target population, comprising overnight express and long-haul operations. Third, the drivers will use the DDWS in realistic and normal operating conditions (i.e., actual delivery runs). Fourth, the evaluation protocol will focus on operational measures to determine system benefits, liabilities, and user acceptability. The Volpe Center, a research arm of the US DOT and the independent evaluator for this FOT, will lead these analyses. VTTI's primary goal in this FOT is to collect the data to support Volpe's analyses.

Anticipated Contributions of Findings

Given the serious problem of drowsy-driver crashes in the trucking industry, the potential safety benefits from a drowsiness monitor are great. However, up until this point, there have been no long term studies on the effectiveness of such a device. The current study will use an on-road experimental approach where drivers will use the DFM as they operate their normal delivery runs.

Collection of data through on-road experimentation has the benefit of allowing substantial “near-crashes” and other critical incident data to be collected. Near-crash analysis is a valid safety measure of effectiveness that occurs at much higher frequencies than accidents of any severity. In determining the safety benefits of the DFM, an examination of the frequency of near-crashes in baseline and treatment conditions will be made. The impact that the DFM has on reducing critical incidents and improving sleep hygiene will be two important areas that will be investigated in this research. The purpose for involving human participants is that critical incident data can not be readily obtained through other observational data gathering methods.

2. PROCEDURES

Experimental Design

The experimental design employed in this FOT is based on a trade study of six different experimental designs (Popkin, Wilson, & Howarth, 2003). The experimental design selected is A^3B^9; $A^2B^8A^2$, where *A* represents the baseline condition where the interface of the DFM is turned off, and *B* represents the treatment condition where the interface is turned on. When the interface is off, it does not provide any visual or auditory alerts but will monitor the driver (eye closures). The DFM provides visual and auditory alerts when the interface is on. The superscript number next to the capital letters indicates the number of weeks that the sequence will last: A^3B^9 indicates that the baseline sequence will last 3 weeks, followed by 9 weeks of the treatment sequence (12 weeks total). Seventy-five percent of the study participants will follow the A^3B^9 model, while the remaining 25 percent will follow the $A^2B^8A^2$ model.

In order for Volpe to have the statistical power necessary to conduct the analyses, 12 weeks of “clean” data are needed. Clean data refers to data where the on-board sensors are working appropriately and the truck is operating properly. It is estimated that, for each driver, it will take as many as 16 weeks to collect 12 weeks of “clean” data. As such, each driver is being recruited to participate for up to 16 weeks.

VTTI will recruit 102 drivers from two trucking fleets. Fifty-one drivers will be recruited from each fleet. Seventy-six drivers will be assigned to Group 1 and 26 will be assigned to Group 2. Table 1 shows the baseline and treatment sequences assigned for Group 1 and Group 2 based on the number of the week.

Table 1. Baseline (A) and Treatment (B) sequences for the 12 weeks.

Group for Drivers	Number of drivers at fleet	Number of Weeks											
		1	2	3	4	5	6	7	8	9	10	11	12
Group 1	76	A	A	A	**B**	**B**	**B**	**B**	**B**	**B**	**B**	**B**	**B**
Group 2	26	A	A	**B**	**B**	**B**	**B**	**B**	**B**	**B**	**B**	A	A

Two truck fleets will participate in this study. One fleet will be an overnight express, less-than-truckload operation and the second will be a long-haul, truck-load operation. Recruitment of these fleets will be completed by December, 2003. VTTI will instrument 17 trucks from each fleet (34 trucks total). As indicated, drivers will drive an instrumented truck for up to 16 weeks (to collect 12 weeks of clean data). After 12 weeks of clean data have been collected, another driver will then drive the instrumented truck. Data collection will last up to one year, with three drivers operating a single instrumented truck. Table 2 shows the truck and driver rotations for one fleet; the trucks and drivers in the second fleet will rotate in a similar manner.

Table 2. Estimated driver and truck rotations for one fleet with 51 drivers and 17 trucks.

	Cycle 1 Week 1 - 16		Cycle 2 Week 1-16		Cycle 3 Week 1-16	
	Driver assigned	Truck used	Driver assigned	Truck used	Driver assigned	Truck used
Group 1	Driver 1 -13	Truck 1-13	Driver 18-30	Truck 1-13	Driver 35-46	Truck 1-12
Group 2	Driver 14 -17	Truck 14 -17	Driver 31-34	Truck 14 -17	Driver 47-51	Truck 13 -17

Driver Recruitment

It is anticipated that after companies have been recruited, driver management will approach drivers with the offer to participate. All participation will be on a volunteer basis. A list of interested drivers and phone numbers will be collected by the company and provided to the research team. A researcher will contact interested drivers and administer a brief screening survey to assess their suitability for the study.

As indicated, 102 drivers (51 drivers from each fleet) will participate in this study. There are <u>no</u> age or gender restrictions for participation. Because the DFM does not work reliably for all drivers who wear eye glasses, some drivers who wear glasses may be restricted from participating (this issue is described later). Drivers will be selected to participate based on their responses to the survey and on whether or not the DFM works reliably for them in a static test.

Equipment

The potential safety benefits associated with the DFM are the primary focus of this research. The DFM provides an estimate of Perclos, or the percentage of time that the driver's eyes are closed or nearly closed over a specified time interval (1 minute, 3 minutes, or 5 minutes). The DFM consists of an Infrared (IR) Camera, signal-processing electronics, and a Driver Vehicle Interface (DVI). The DVI provides an audible and visual warning to the driver when Perclos reaches a predetermined level. The DFM was developed by Attention Technologies Inc. (ATI).

To study the potential safety benefits associated with the DFM, an on-board data acquisition system (DAS) is required. The DAS consists of a variety of sensors to measure driver input (e.g., lane position, velocity) and video cameras to record the driving scenario and measure driver drowsiness and attention (e.g., eye closure, glance location). Four video cameras will be used to record the following: (i) forward roadway, (ii) driver's face, (iii) rearward left, and (iv) rearward right. Video of the driver's face will allow off-line, manual, direct calculation of Perclos values for comparison with the output from the DFM. Images of the driving scene (forward and rearward) will provide a record of driving events as they unfold. The digital video files will not contain continuous audio. However, the DAS has been designed so that the driver can press a button and record a verbal comment lasting up to 1-minute. The DFM and DAS will be installed into in-service trucks provided for use in the study by the fleets.

Experimental Protocol

Drivers will indicate their interest in participating in the study by completing the initial screening survey. From those interested, a sample of drivers will be selected who best meet the study requirements (e.g., drive at night, have a steady work history- not likely to drop out of the study). From this sample, drivers will be contacted and asked to perform a test with the DFM in a static setting. This static test will either occur with the system mounted on the dash of a truck, or with the system mounted on a table in a room. The driver will perform several mock/pretend eye closures to determine if the DFM works for them in this static environment. If not, they will be paid and thanked for their interest (detailed information on subject payment is provided later). If the DFM does work for them, they will complete the Informed Consent form (attached with this document) and their visual acuity and hearing level will be measured and documented. A copy of the informed consent will be provided to the driver. At this time, the driver will be given a pre-study survey to take with them and complete at home. This survey includes demographic questions and questions about past driving experience. They will be asked to complete this survey and return it within a few days.

Before conducting the on-road study, researchers from VTTI will conduct a fatigue management course and DFM instructional session at the fleet location. Fleet managers and drivers will be invited to participate. Drivers unable to attend the fatigue management course will be provided with a summary of the materials presented. DFM instruction will be conducted immediately following the fatigue management course with the group of attendees. Additional training will be conducted individually with each driver prior to their beginning their turn in the study. Note that information about the trucking company will be collected from the Fleet Manager via a survey.

Drivers will be randomly assigned to either Group 1 or Group 2 for the on-road data collection. Just prior to beginning the first drive, each driver will be provided detailed instruction about the purpose and operation of the DFM. A User's Manual and a one-page summary sheet of the DFM User's manual will be also be given to the driver. The driver will practice using the DFM in the truck. The driver will be instructed to wear an actigraph unit on the wrist of his/her dominant hand. An actigraph unit is a "wrist watch" type activity-monitoring device used to assess a participant's sleep quantity and sleep quality. This device is the size of a wristwatch and is worn like a wristwatch. It provides an indication of whether or not the wrist is in motion and stores the data as a function of time. In effect, it indicates whether subjects "toss and turn" while sleeping. During the day, the device also provides an indication of activity level. The actigraph unit is self-contained and makes no electrical contact with the subject.

After the driver has strapped an actigraph watch on the wrist of his/her dominant hand, he/she will be taken to the instrumented truck. The on-road data collection will begin once the driver becomes comfortable with the data collection procedure. The drivers will drive the instrumented truck as they normally do on their job. The drivers will be informed that downloading data from the truck and actigraph watch will be conducted by a researcher once a week at the fleet distribution center.

A researcher from VTTI will remotely check the DFM and DAS conditions via cellular phone (connecting directly to the on-board DAS) every morning during the on-road data collection. Video camera conditions will also be checked to make sure that the driver's eyes are being recorded.

When the 12-week data collection is completed, the driver will fill out the post-study survey and debriefing survey, will be thanked for their participation, and will sign a payment sheet. The payment will be sent to the driver in the form of a check.

The cycle of the DFM test, fatigue management course and DFM practice, and on-road data collection will be continued with additional drivers: before the first 17 drivers complete their 12-week data collection, VTTI will contact another group of drivers for the DFM test who were screened from the pre-participation survey. The cycle will be continued to achieve data collection with 51 drivers for up to 16 weeks at each fleet.

Compensation

Drivers will receive $20 for their participation in the DFM test, $50 for the fatigue management course, and $100 per week of participation in the on-road study. The total data collection will last 12 straight weeks or until 12-weeks worth of data is collected by the end of 16th week. The driver will be paid a bonus of $230 for completing the data collection. Therefore, a driver who completes the study is expected to be compensated $1500 (i.e., $20 for DFM test + $50 for fatigue management course + $1200 for FOT + $230 for bonus). The $20 for the DFM screening test and the $50 for the fatigue management course will be paid in cash immediately after participation in these activities. Compensation for participating in the 12 driving weeks and the bonus will be paid by check after the driver has completed the study.

3. RISKS AND BENEFITS

Risks

There are some risks and discomforts to which drivers will be exposed in volunteering for this research. The risks are:

1. The risk of an accident associated with driving a truck as they usually do.
2. The slight additional risk of an accident that might possibly occur while pressing a button to indicate that a critical incident has occurred.
3. The slight additional risk of an accident that might possibly occur while interacting with the DFM.
4. While driving the vehicle, drivers will be videotaped by a camera. Because of this, we ask that drivers not wear sunglasses. If this, at any time during the course of driving, impairs the ability to drive the vehicle safely, the driver may wear the glasses. Otherwise, we ask that drivers not do so.

The following precautions will be taken to ensure minimal risk to the subjects:

1. Drivers will be trained on how to operate the critical incident button and the DFM. Namely, to do so after an incident has occurred and not during the incident.
2. All data collection equipment is mounted such that, to the greatest extent possible, it does not pose a hazard in any foreseeable way.
3. The driver will be instructed to follow his/her company's safety protocol.

There is not expected to be any additional risk posed by having the DFM in the vehicle. The DFM involves infrared beams that detect retinal reflectance to determine a percentage of eyelid closure. The beams are emitted from a small mounted camera that will in no way be in contact with any part of the driver's body. When compared to a similar device that has been judged to be safe by an expert, Dr. David H. Sliney (a Physicist in the Laser/Optical Radiation Program with the U.S. Army) concluded that the camera's illumination system has irradiation levels well below the safe value of 10-mW/cm^2.

Benefits

No promise or guarantee of benefits is being made to encourage drivers to participate. Research, such as that being conducted here, is important because it improves driving safety and helps reduce crashes. Drivers' participation is necessary to assess the efficacy of a drowsiness monitor aimed at reducing fatigue-related crashes. Past experience with previous studies involving heavy-vehicle drivers indicates that drivers may find the study interesting.

4. CONFIDENTIALITY/ANONYMITY

The data gathered in this experiment will be treated with confidentiality. Shortly after participating, drivers' names will be separated from the data and replaced with a number. That is, drivers' data will not be attached to their name, but rather to a number (e.g., Driver No.1).

While driving the vehicle, a camera will videotape the face with some additional space around the head to accommodate any head-movements. Additionally, video cameras will capture views looking in front and to both sides of the vehicle.

If a critical incident occurs, drivers will be asked to press a button on the dash. This will place a flag in the data set so researchers can more easily locate the event. Also, pressing the button opens up an audio channel for 1-minute. In this 1-minute, drivers can describe the critical incident that occurred.

The video and other data from this study will be stored in a secured area at the Virginia Tech Transportation Institute and at a secure location near the fleet location. Access to the digital video files will be under the supervision of the Principal Investigator and lead researcher involved in the project. The video files will be accessible to the government sponsor and to those researchers and data analysts associated with this project and for follow-up analytical projects, at VTTI and the Volpe Center (the independent evaluator for this project). The video files will not be released to unauthorized individuals without the participant's written consent.

In addition, a Certificate of Confidentiality will be applied for, which grants confidentiality to research participants. This confidentiality is provided for by the Public Health Services Act (§ 301(d), 42 U.S.C. 8241(d)). It ensures protection against compulsory legal process for personally identifiable research information. For this reason, a copy of driver's data cannot be given to him/her or anyone else.

VTTI will not release the tapes to unauthorized individuals without the driver's written consent. The informed consent (Attachment B) includes a section in which the driver can volunteer to allow his/her personal data (e.g., video) to be used in support of conference presentations and other forums that serve to promote research.

5. INFORMED CONSENT

Please see attachment labeled *VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY: Informed Consent for Participants of Investigative Projects.*

6. REFERENCES

Popkin, S., Wilson, B. & Howarth, H. (2003). *Drowsy Driver Warning System Field Operational Test: Experimental Design Considerations*. Cambridge, MA: Volpe National Transportation Systems Center.

Wierwille, W. W., Hanowski, R. J., Olson, R. L., Dinges, D. F., Price, N. J., Maislin, G., Powell, J. W. IV, Ecker, A. J., Mallis, M. M., Szuba, M. P., Ayoob, A., Grace, R. and Steinfeld, A. (2002). *NHTSA drowsy driver detection and interface project-Draft final report.* Contract No. DTNH22-D- 00-07007, Task Order 1. Blacksburg, VA: Virginia Tech Transportation Institute.

ATTACHMENT: INFORMED CONSENT FORM

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Informed Consent for Participants

in Research Projects Involving Human Subjects

Title of Project: Drowsy Driver Warning System (DDWS) Field Operational Test (FOT)

Task 18: Collect On-Road Data

Investigators: Dr. Richard Hanowski, Dr. Ronald Knipling, Akiko Nakata

I. Purpose of this Research/Project

The purpose of this study is to evaluate the safety benefits of a device that monitors driver drowsiness. This device is called a Driver Fatigue Monitor (DFM). As you know, drowsiness is of particular safety concern in the trucking industry. The DFM monitors drivers' eye closures and provides an alert if it detects that the driver is becoming drowsy. This study will investigate how well this system works at improving safety, and determine how drivers feel about the device.

II. Procedures

We would like you to drive your truck and complete your work route as you normally do. A DFM has been mounted on the dash of your truck. In addition, a variety of other data collection equipment has been instrumented on your truck. This data collection equipment is necessary for us to understand the safety benefits of the DFM.

In addition to driving your truck, there are several other tasks that you will need to complete:

1. Read and sign this Informed Consent Form (if you agree to participate).
2. Wear, for the length of your participation, a wrist activity monitor.
3. Complete pre- and post-study surveys.
4. Participate in a training session that will include a fatigue management course and information about the study.

The study will last up to 16 weeks, but may be completed in as little as 12 weeks. For the research team to conduct a thorough analysis of the DFM, we need 12 weeks of "clean" data (e.g., data where all the sensors are working properly) and it may take 16 weeks to collect this data. We are collecting data from many truck drivers like yourself (102 drivers total). To understand if the DFM might benefit the trucking industry, it is important that you use the device as it is intended for the entire study period.

III. Risks and Discomforts

There are some risks and discomforts to which you will be exposed in volunteering for this research. The risks are:

1. The risk of an accident associated with driving a truck as you usually do.
2. The slight additional risk of an accident that might possibly occur while pressing a button to indicate that a critical incident has occurred.
3. The slight additional risk of an accident that might possibly occur while interacting with the DFM.
4. While driving the vehicle, you will be videotaped by a camera. Because of this, we ask that you not wear sunglasses. If this, at any time during the course of your driving, impairs your ability to drive the vehicle safely, you may wear the glasses. Otherwise, we ask you not to do so.

The following precautions will be taken to ensure minimal risk to the subjects:

1. Drivers will be trained on how to operate the critical incident button and the DFM.
2. All data collection equipment is mounted such that, to the greatest extent possible, it does not pose a hazard to you in any foreseeable way.
3. You will be instructed to follow your company's safety protocol.

There is not expected to be any additional risk posed by having the DFM in the vehicle. The DFM involves infrared beams that detect retinal reflectance to determine a percentage of eyelid closure. The beams are emitted from a small mounted camera that will in no way be in contact with any part of your body. When compared to a similar device that has been judged to be safe by an expert, Dr. David H. Sliney (a Physicist in the Laser/Optical Radiation Program with the U.S. Army) concluded that the camera's illumination system has irradiation levels well below the safe value of 10-mW/cm^2.

IV. Benefits

No promise or guarantee of benefits is being made to encourage you to participate. Research, such as that being conducted here, is important because it improves driving safety and helps reduce crashes. Drivers' participation is necessary to assess the efficacy of a drowsiness monitor aimed at reducing fatigue-related crashes. Past experience with previous studies involving heavy-vehicle drivers indicates that you may find the study interesting.

V. Extent of Anonymity and Confidentiality

The data gathered in this experiment will be treated with confidentiality. Shortly after participating, your name will be separated from the data and replaced with a number. That is, your data will not be attached to your name, but rather to a number (e.g., Driver No.1).

While you are driving the vehicle, a camera will videotape your face with some additional space around the head to accommodate any head-movements. Additionally, video cameras will capture views looking in front, and to both sides of the vehicle.

If a critical incident occurs, you will be asked to press a button on the dash. This will place a flag in the data set so researchers can more easily locate the event. Also, pressing the button opens up an audio channel for 1-minute. In this 1-minute, you can describe the critical incident that occurred.

The video and other data from this study will be stored in a secured area at the Virginia Tech Transportation Institute. Access to the digital video files will be under the supervision of the Principal Investigator and lead researcher involved in the project. The video files will be accessible to the government sponsor and to those researchers and data analysts associated with this project and for follow-up analytical projects, at VTTI and the Volpe Center (the independent evaluator for this project). The video files will not be released to unauthorized individuals without your written consent.

In addition, a Certificate of Confidentiality has been obtained[2], which grants confidentiality to research participants. This confidentiality is provided for by the Public Health Services Act (§ 301(d), 42 U.S.C. 8241(d)). It ensures protection against compulsory legal process for personally identifiable research information. For this reason, a copy of your data cannot be given to you or anyone else.

VI. Compensation

You will be paid for participating in this FOT. You will be paid $20 for a DFM screening test, and $50 for the fatigue management course/DFM training session. During the on-road data collection, you will be paid $100 per week for driving the instrumented DFM truck. You will be paid a bonus of $230 for completing the study. The total payment for 12 weeks of data collection will be $1500 ($20 + $50 + $1200 + $230).

You will be paid in cash, immediately after completion, for the DFM screening test ($20) and the fatigue management course/DFM training session ($50). You will be paid for the on-road data collection at the end of the study. Payment for the on-road data collection part of the study will be made by check and mailed to you after your participation in the study is over.

XIII. Freedom to Withdraw

As a participant in this research, you are free to withdraw at any time without penalty. If you choose to withdraw, you will be compensated for the portion of time of the study for which you participated. However, you will not be eligible for the bonus. Furthermore, you are free not to answer any question or respond to experimental situations without penalty.

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[2] This statement will be added if the Certificate is granted. However, the application process is not yet completed because it is dependent on IRB approval.

IX. Approval of Research

This research project has been approved, as required, by the Institutional Review Board for Research Involving Human Subjects at Virginia Polytechnic Institute and State University.

September 11, 2003______________ September 10, 2004____________________

IRB Approval Date Approval Expiration Date

X. Subject's Responsibilities

I voluntarily agree to participate in this study. I have the following responsibilities:

1. To be physically free from any illegal substances (i.e., drugs) or alcohol while driving,
2. To conform to the laws and regulations of driving on public roadways,
3. To follow the experimental procedures as well as you can,
4. To perform the driving task without interfering with the operation of the DDWS or other on-board equipment, and
5. To inform the experimenters if you incur difficulties of any type.

XI. Subject's Permission

I have read and understand the Informed Consent and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent for participation in this project.

If I participate, I understand that I may withdraw at any time without penalty. I agree to abide by the rules of this project.

____Date________________________

Subject signature

APPENDIX C: CERTIFICATE OF CONFIDENTIALITY

1. *Name and address of applicant research institution:*

   Virginia Tech Transportation Institute (VTTI)
   3500 Transportation Research Plaza
   Blacksburg, Virginia 24061

2. *Sites where the research will be conducted and a brief description of the facilities available for the conduct of the research. Please indicate if this is a multi-site project:*

   The data collection will be based on two truck fleets in this study. One fleet will be an overnight express, less-than-truckload operation and the second will be a long-haul, truck-load operation. One researcher will be working directly with the drivers at the truck distribution site. Other project researchers will be located at the primary VTTI facility in Blacksburg, Virginia.

3. *Title of the research project:*

   "Drowsy Driver Warning System (DDWS) Field Operational Test (FOT)"
   IRB Number: 03-437

4. *Source and number of the supporting grant:*

   National Highway Traffic Safety Administration
   Office of Crash Avoidance
   Contract DTNH22-00-C-07007

5. a. *Requirement: IRB approval*

   Requirement satisfied: September 11, 2003

   b. *Documentation of IRB approval*

   Please see attached memo.

   c. *Documentation of IRB qualifications*

   The Virginia Tech Institutional Review Board
   Assurance number assigned by OHRP: **FWA 00000572**
   IRB Number: **IRB 00000667**

6. a. *Name, title, mailing and email addresses, telephone and fax numbers of the Applicant as well as name and title of other key personnel. Also include a brief summary of the scientific training of the Applicant and key personnel:*

Name	Title	Email Address	Telephone #	Mailing Address	Fax #
Dr. Rich Hanowski	Leader, Truck and Bus Safety Group	hanowski@vtti.vt.edu	(540) 231-1513	VTTI 3500 Transportation Research Plaza Blacksburg, Virginia 24061	(540) 231-1555
Dr. Ron Knipling	Senior Research Scientist	rknipling@vtti.vt.edu	(703) 538-8439	VT Northern Virginia Center 7054 Haycock Rd. Falls Church, Virginia 22043	(703) 538-8845
Ms. Akiko Nakata	Senior Research Associate	anakata@vtti.vt.edu	(540) 231-1589	VTTI 3500 Transportation Research Plaza Blacksburg, Virginia 24061	(540) 231-1555

b. *Brief Summary of Scientific Training:*

Dr. Richard Hanowski

Dr. Hanowski is the Leader of the Truck and Bus Safety Group at the Virginia Tech Transportation Institute. He has authored over 70 scientific articles, book chapters, and technical reports and is currently the PI on over $4 million of contract research. His research experience is in transportation human factors with both heavy and light vehicles, laboratory & field testing, real-time automobile & heavy vehicle simulation, human factors design guideline development, older driver investigation, collision warning, and Intelligent Transportation Systems. Dr. Hanowski is the past Chairman of the ITS America, Safety & Human Factors Committee (2000-2002).

Dr. Ron Knipling

Dr. Knipling served for six years as Chief of the Research Division at the Federal Motor Carrier Safety Administration (FMCSA). During the previous six years, he was an Engineering Research Psychologist in the Office of Crash Avoidance Research of the National Highway Traffic Safety Administration (NHTSA). Prior to joining the U.S. DOT, Dr. Knipling was Principal Research Scientist at Allen Corporation of America, a consulting firm serving NHTSA and other Federal agencies. During this period, he coordinated training of NHTSA National Accident Sampling System (NASS) researchers, and managed research teams specializing in both crash data collection and analysis. Dr. Knipling received his Ph.D. in Experimental Psychology from the University of Maryland, and has ten years of university-level teaching experience.

Akiko Nakata

Ms. Nakata has spent the past two and half years investigating transportation human factors issues. In that time, she has conducted research on visual symbols for In-Vehicle Information System (IVIS) devices and has worked on software development for driver-performance models for highway design, has reviewed cell-phone use in vehicles and IVI-related HF research, and has investigated information design requirements for public-transit websites. Most of these research projects were federally funded by the Federal Highway Administration and the National Highway Traffic Safety Administration. Ms. Nakata received her M.S. in Human Factors Psychology from Rensselaer Polytechnic Institute in 2000.

7. *Beginning date and expected end date of the project:*

   The project began on October 1, 2002, and data collection is expected to begin in February, 2004. Completion is scheduled for September 30, 2005.

8. *Concise description of project aims and research methods:*

   This Field Operational Test (FOT) has two purposes. The first purpose is to test the effectiveness and operational capabilities, limitations, and characteristics of a device that monitors drowsiness in drivers. This device is a vehicle-based Driver Fatigue Monitor (DFM) that works by monitoring a driver's eye-closure. The second purpose is to assess drivers' acceptance of the DFM.

   There are four general requirements associated with meeting these purposes. First, the evaluation will occur in a naturalistic driving environment, and data must be collected from actual truck drivers driving a commercial truck. Second, the participant population will be representative of the target population comprising overnight express and long haul operations. Third, the drivers will use the DFM in realistic and normal operating conditions (i.e., actual delivery runs). Fourth, the evaluation protocol will focus on operational measures to determine system benefits, liabilities, and user acceptability. VTTI will administrate pre-study, post-study, and debriefing surveys with the drivers to provide them with the opportunity to express their opinions about the DFM as well as fatigue-related issues.

VTTI will recruit 102 drivers with a Class-A Commercial Driver's License (CDL). These drivers will be recruited from two truck fleets, 51 drivers from each fleet. Driver qualification will include: (i) regularly driving at night, (ii) having a steady work history, and (iii) having acceptable visual acuity (corrected to at least 20/40) and hearing level (less than 40 dB for 500, 1000, and 2000-Hertz tone, respectively). VTTI will instrument 34 commercial trucks with the DFM and data acquisition system, and these instrumented trucks will be used for one year for data collection on the road. A rotation of the 34 trucks for 102 drivers is shown in Table 1.

Table 1. Rotation of 34 trucks for 102 drivers.

	Data collection period		
	Month 1 - 4	Month 5 – 8	Month 9 - 12
Driver assigned	Driver 1 -34	Driver 35 – 68	Driver 69 -102
Truck used	Truck 1 -34	Truck 1 -34	Truck 1 -34

9. *A description of means used to protect subjects' identities:*

Video cameras will be mounted in the vehicle for recording purposes. These four cameras will record the following information:

- Camera 1: Driver's face
- Camera 2: Forward view
- Camera 3: Rear, left-side view of vehicle off to the left of the vehicle
- Camera 4: Rear, right-side view off to the right of the vehicle

Video information will be taken during the course of data collection. The data gathered in this experiment will be treated with confidentiality. Shortly after participating, drivers' names will be separated from their data. A coding scheme will be employed to identify the data by subject number only (e.g., Driver No. 1). Video will be transmitted digitally and will be stored on a project dedicated server.

Encrypted data will be downloaded and will be stored on a DVD. All DVDs will be kept in a secured area and will be housed on an independent network controlled by the Principal Investigators. Access to the digital video files will be under the supervision of the Principal Investigator and lead researchers involved in the project. Access to the data will be under the supervision of Dr. Rich Hanowski, Dr. Ron Knipling, and Akiko Nakata. The video files will be accessible to the government sponsor and to those researchers and data analysts associated with this project and for follow-up analytical projects at VTTI and the Volpe Center (the independent evaluator for this project). The video files will not be released to unauthorized individuals without the driver's written consent.

The driver will be informed that if they are involved in a crash while participating in this study, the data collection equipment in the vehicle will likely capture the events leading up to the event. The driver will be advised that data collection equipment or videotapes should ***not*** be given to police officers or to any other party. Drivers will further be advised that they are under no legal obligation to mention that that they are participating in this study. Drivers will be told that they have the right to withdraw their data from the study.

10. *Reasons for requesting a Certificate of Confidentiality:*

    VTTI believes that a Certificate of Confidentiality is vital to the successful completion of this research project. Among the reasons that a certificate is merited in this case are the necessity of recruiting willing participants (commercial truck drivers) and the assurance of valid data, thus of meaningful results and conclusions.

    A crucial element of this study is that truck drivers willingly participate and that during their participation, they respond as they normally would if they were not involved in an experiment. It is believed that drivers either would not be willing to participate or would not react appropriately if they were not protected by confidentiality. If the drivers' concerns about confidentiality issues caused them to respond in an unusual manner, the validity of the data would be compromised.

    The performance data, as well as video recordings, could contain evidence that might incriminate the driver should a recorded collision be investigated. No continuous audio information is being recorded in order to further respect the subjects' privacy. An audio channel can be opened by the driver, at the driver's discretion, to comment about the driving situation (e.g., to inform researches of near-crash). The video cameras have been positioned carefully so that no passenger is visible (as they have not signed an informed consent form) and so that no passenger behavior will be recorded in any way. The data collection system is activated by the ignition of the vehicle, so no information will be recorded when the vehicle is not in use.

11. *Informed consent forms for human subjects, as approved by the IRB (attach copy):*

    Informed consent form for the truck drivers is attached as Appendix.

12. *Research not funded by NIH in which drugs will be administered to human subjects must provide the following additional information:*

    - Identification of drugs to be administered;
    - Description of methods for administration of theses drugs, including a statement of dosages;
    - Evidence that individuals who will receive the drugs are authorized to do so under applicable Federal and Sate law.

    No drugs will be administered.

13. *All research in which a controlled drug or drugs will be administered must submit a copy of the Drug Enforcement Administration Certificate of Registration (BND Form 223) under which the research project will be conducted.*

    No drugs will be administered.

14. *If the research project is testing for reportable communicable diseases, the applicant must submit information relating to its compliance with State reporting laws as specified in the August 9, 1991 memorandum from the Assistant Secretary of Health.*

    This project is not testing for reportable communicable diseases.

ASSURANCES

The following assurances are required and the following information should be inserted verbatim into the Certificate application letter. Both the PI and the Institutional Official must sign this letter:

1. This institution agrees to use the Certificate of Confidentiality to protect against the compelled disclosure of personally identifiable information and to support and defend the authority of the Certificate against legal challenges.
2. The institution and personnel involved in the conduct of the research will comply with the applicable Federal regulation for the protection of human subjects or, if no such Federal regulation is otherwise applicable, they will comply with 45 CFR Part 46.
3. This Certificate of Confidentiality will not be represented as an endorsement of the project by the DHHS or NIH or used to coerce individuals to participate in the research project.
4. All subjects will be informed that a Certificate has been issued, and they will be given a description of the protection provided by the Certificate.
5. Any research participant entering the project after expiration or termination of the Certificate will be informed that the protection afforded by the Certificate does not apply to them.

____

Signature of Principal Investigator Richard Hanowski

____

Signature of Institutional Official David Moore

ORIGINAL APPROVAL LETTER FROM VIRGINIA TECH IRB

Virginia Tech
VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Institutional Review Board

Dr. David M. Moore
IRB (Human Subjects) Chair
Assistant Vice Provost for Research Compliance
CVM Phase II - Duckpond Dr., Blacksburg, VA 24061-0442
Office: 540/231-4991; FAX: 540/231-6033
e-mail: moored@vt.edu

September 12, 2003

MEMORANDUM

TO: Richard Hanowski Virginia Tech Transportation Instit 536

FROM: David M. Moore

SUBJECT: **Expedited Approval** – "Drowsy Driver Warning System(DDWS) Field Operational Test(FOT) Task 18: DDWS and Data Acquisition System(DAS) On-Road Data Collection"– IRB # 03-437

This memo is regarding the above-mentioned protocol. The proposed research is eligible for expedited review according to the specifications authorized by 45 CFR 46.110 and 21 CFR 56.110. As Chair of the Virginia Tech Institutional Review Board, I have granted approval to the study for a period of 12 months, effective September 11, 2003.

Approval of your research by the IRB provides the appropriate review as required by federal and state laws regarding human subject research. It is your responsibility to report to the IRB any adverse reactions that can be attributed to this study.

To continue the project past the 12 month approval period, a continuing review application must be submitted (30) days prior to the anniversary of the original approval date and a summary of the project to date must be provided. My office will send you a reminder of this (60) days prior to the anniversary date.

Cc: File
Department Reviewer: Suzanne E. Lee VTTI 0536
OSP 0170

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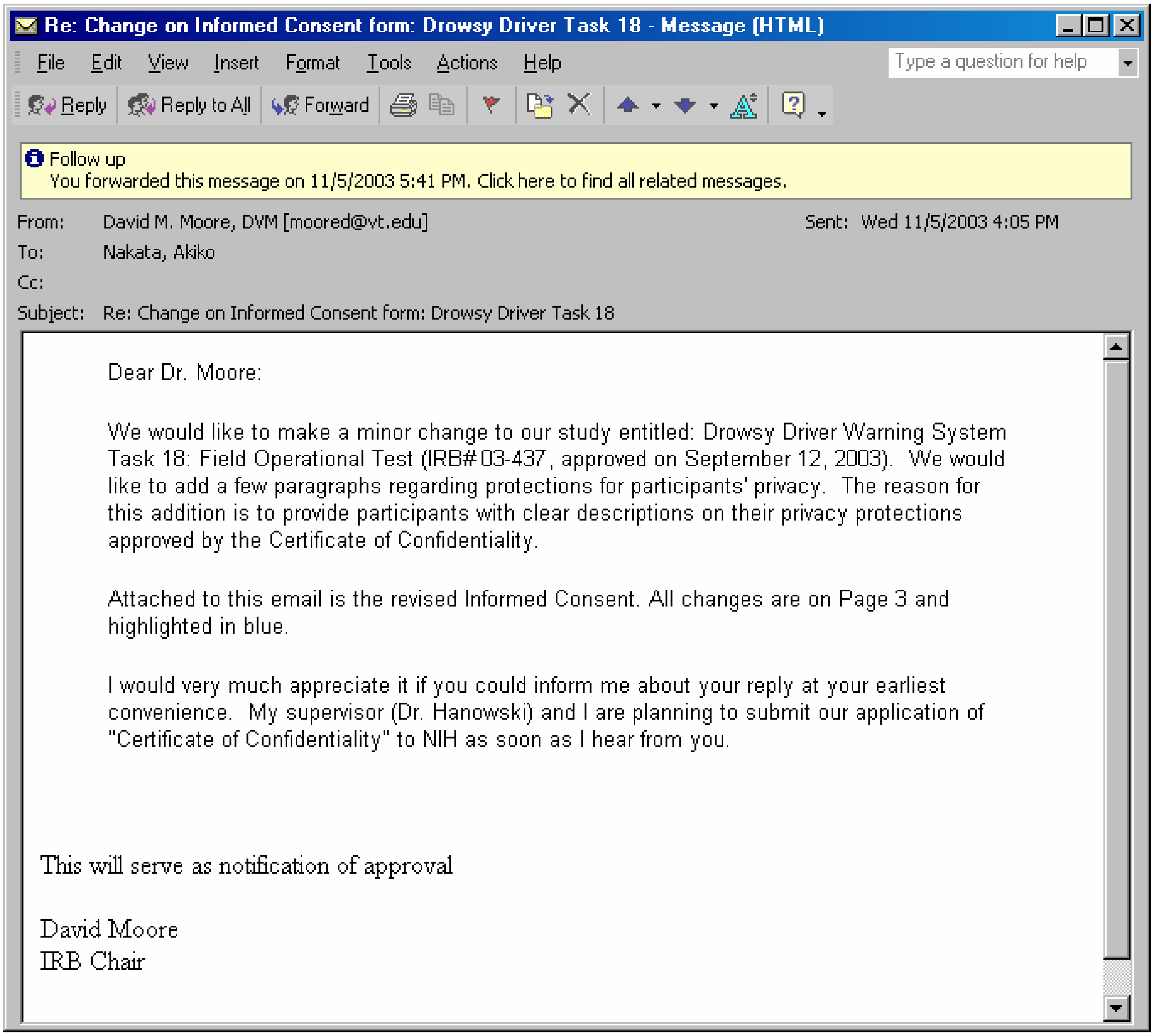
APPROVAL EMAIL FROM VIRGINIA TECH IRB



Re: Change on Informed Consent form: Drowsy Driver Task 18 - Message (HTML)

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From: David M. Moore, DVM [moored@vt.edu]
Sent: Wed 11/5/2003 4:05 PM
To: Nakata, Akiko
Cc:
Subject: Re: Change on Informed Consent form: Drowsy Driver Task 18

Dear Dr. Moore:

We would like to make a minor change to our study entitled: Drowsy Driver Warning System Task 18: Field Operational Test (IRB# 03-437, approved on September 12, 2003). We would like to add a few paragraphs regarding protections for participants' privacy. The reason for this addition is to provide participants with clear descriptions on their privacy protections approved by the Certificate of Confidentiality.

Attached to this email is the revised Informed Consent. All changes are on Page 3 and highlighted in blue.

I would very much appreciate it if you could inform me about your reply at your earliest convenience. My supervisor (Dr. Hanowski) and I are planning to submit our application of "Certificate of Confidentiality" to NIH as soon as I hear from you.

This will serve as notification of approval

David Moore
IRB Chair

APPENDIX D: FREQUENCY AND ODDS RATIO TABLES FOR DROWSY-RELATED EVENTS, NON-DROWSY EVENTS, DROWSY-RELATED BASELINES AND NON-DROWSY BASELINES

Table 1. Drowsy-related critical incidents, non-drowsy critical incidents and baseline incidents by time of day.

Time of Day	Drowsy-Related Incidents	Non-Drowsy Incidents	Drowsy-Related Baselines	Non-Drowsy Baselines	Odds Ratio	Lower CL	Upper CL
0:00 – 0:59	8	4	13	20	3.08	0.77	12.34
1:00 – 1:59	5	1	14	8	2.86	0.28	28.96
2:00 – 2:59	2	3	15	9	0.40	0.06	2.87
3:00 – 3:59	4	4	14	25	1.79	0.39	8.27
4:00 – 4:59	2	3	12	15	0.83	0.12	5.82
5:00 – 5:59	2	3	11	11	0.67	0.09	4.80
6:00 – 6:59	7	4	13	13	1.75	0.41	7.45
7:00 – 7:59	3	12	10	16	0.40	0.09	1.78
8:00 – 8:59	6	11	6	18	1.64	0.42	6.36
9:00 – 9:59	4	22	8	25	0.57	0.15	2.15
10:00 – 10:59	5	26	5	29	1.12	0.29	4.29
11:00 – 11:59	10	28	8	29	1.29	0.45	3.76
12:00 – 12:59	5	23	11	34	0.67	0.21	2.19
13:00 – 13:59	3	19	7	24	0.54	0.12	2.38
14:00 – 14:59	14	23	4	30	4.57	1.33	15.73
15:00 – 15:59	12	36	9	37	1.37	0.52	3.65
16:00 – 16:59	17	32	11	22	1.06	0.42	2.70
17:00 – 17:59	10	21	9	34	1.80	0.63	5.15
18:00 – 18:59	8	21	11	38	1.32	0.46	3.78
19:00 – 19:59	7	15	16	24	0.70	0.23	2.10
20:00 – 20:59	13	15	19	21	0.96	0.36	2.52
21:00 – 21:59	7	13	27	30	0.60	0.21	1.72
22:00 – 22:59	9	9	19	21	1.11	0.36	3.36
23:00 – 23:59	7	3	18	31	4.02	0.92	17.51
Total	170	351	290	564			

Table 2. Drowsy-related critical incidents, non-drowsy critical incidents and baseline incidents by day of shift.

Day of Shift	Drowsy-Related Incidents	Non-Drowsy Incidents	Drowsy-Related Baselines	Non-Drowsy Baselines	Odds Ratio	Lower CL	Upper CL
1	47	102	104	183	0.81	0.53	1.24
2	30	81	65	145	0.83	0.50	1.38
3	23	62	41	77	0.70	0.38	1.28
4	20	28	21	49	1.67	0.77	3.59
5	12	16	20	34	1.28	0.50	3.23
6	5	9	6	15	1.39	0.33	5.90
7	4	14	7	11	0.45	0.10	1.93
Total	141	312	264	514			

Table 3. Drowsy-related critical incidents, non-drowsy critical incidents and baseline incidents by day of week.

Day of Week	Drowsy-Related Incidents	Non-Drowsy Incidents	Drowsy-Related Baselines	Non-Drowsy Baselines	Odds Ratio	Lower CL	Upper CL
Sunday	14	31	15	38	1.14	0.48	2.73
Monday	24	59	53	109	0.84	0.47	1.49
Tuesday	31	64	66	109	0.80	0.47	1.35
Wednesday	40	68	55	102	1.09	0.66	1.82
Thursday	21	69	52	97	0.57	0.31	1.03
Friday	36	59	35	93	1.62	0.92	2.86
Saturday	9	9	21	40	1.90	0.66	5.52
Total	175	359	297	588			

Table 4. Drowsy-related critical incidents, non-drowsy critical incidents and baseline incidents by driving hour.

Drive Hour	Drowsy-Related Incidents	Non-Drowsy Incidents	Drowsy-Related Baselines	Non-Drowsy Baselines	Odds Ratio	Lower CL	Upper CL
1	21	56	35	81	0.87	0.46	1.64
2	16	29	27	79	1.61	0.76	3.42
3	10	40	22	55	0.63	0.27	1.46
4	13	30	34	47	0.60	0.27	1.32
5	14	29	23	55	1.15	0.52	2.58
6	12	24	32	47	0.73	0.32	1.68
7	12	17	18	31	1.22	0.47	3.11
8	12	24	17	35	1.03	0.42	2.54
9	10	15	15	28	1.24	0.45	3.44
10	9	17	17	16	0.50	0.17	1.44
11	7	13	9	19	0.88	0.26	2.96
Total	136	294	249	493			

Table 5. Drowsy-related critical incidents, non-drowsy critical incidents and baseline incidents by shift hour.

Shift Hour	Drowsy-Related Incidents	Non-Drowsy Incidents	Drowsy-Related Baselines	Non-Drowsy Baselines	Odds Ratio	Lower CL	Upper CL
1	15	30	26	48	0.92	0.42	2.02
2	11	22	19	54	1.42	0.58	3.47
3	8	21	17	42	0.94	0.35	2.53
4	6	16	19	32	0.63	0.21	1.89
5	4	19	11	32	0.61	0.17	2.20
6	3	19	19	37	0.31	0.08	1.17
7	11	11	14	33	2.36	0.83	6.69
8	7	10	19	27	0.99	0.32	3.08
9	1	17	12	24	0.12	0.01	0.99
10	7	13	11	19	0.93	0.29	3.03
11	10	14	10	23	1.64	0.55	4.93
12	6	14	11	14	0.55	0.16	1.89
13	10	13	8	16	1.54	0.47	5.02
14	7	15	7	11	0.73	0.20	2.70
Total	106	234	203	412			

Table 6. Drowsy-related critical incidents, non-drowsy critical incidents and baseline incidents by time since last break.

Time Since Last Break	Drowsy-Related Incidents	Non-Drowsy Incidents	Drowsy-Related Baselines	Non-Drowsy Baselines	Odds Ratio	Lower CL	Upper CL
1	86	176	123	284	1.13	0.81	1.57
2	40	79	76	133	0.89	0.55	1.42
3	17	59	40	74	0.53	0.27	1.03
4	11	20	23	38	0.91	0.37	2.23
5	6	8	14	15	0.80	0.22	2.90
6	1	8	5	6	0.15	0.01	1.64
7	2	4	2	1	0.25	0.01	4.73
8	1	0	2	3	N/A	N/A	N/A
9	0	0	1	1	N/A	N/A	N/A
Total	164	354	286	555			

APPENDIX E: ANSWERS TO QUESTIONS 6 – 9 OF THE HOS QUESTIONNAIRE

Question 6:
How do you think your **amount** of sleep (number of hours of sleep per night) now compares to the amount of sleep that you got under the old hours-of-service regulations (before January 4, 2004)?

<u>I got more sleep under the old</u> hours-of-service regulations (before January 4, 2004)

- “You could stop and take naps and it would not go on your time per day.”
- “During store runs is easier to get home under the old rules.”
- “10 hours is too much time off, it is too easy to get involved in other things (tv, games, conversation, etc.).”
- “I could drive 10 hours, sleep 8 and drive more. I got more miles and I could stop at any time. Now I have to start work and finish in 14 hours regardless if I’m tired.”

<u>I get the same amount of sleep</u> under the revised hours-of-service regulations as I did under the old hours-of-service regulations

- “I still get in bed at the same time.”
- “Well you only sleep the amount of time you would anyway. And if I don’t use the whole 10 hours for sleep I still lay down and rest.”
- “It seems like the older I get, the shorter my periods of sleep get.”
- “Same amount, more dead time.”
- “Too much sleep.”
- “I can only sleep so long.”
- “Always home by 8am, in bed by 9am.”
- “Because our routes are pretty much mark on each run, on the time we leave until the time we return. We have windows of time we relay.”
- “I have a set regulations hours-of-duty.”
- “Nothing changed nobody at home during the day.”
- “Body did not change.”
- “Because I trained my body to go on 8 hours; hard to sleep longer.”
- “Because I usually got up only when I finish my sleep.”
- “There is only 2 hour difference between old and new regs. Got to run harder than before to make miles.”
- “Because under the old rule, driver was able to get 1 or more hours of sleep without using your duty time, you can take a lot more breaks under old rules than new ones.”
- “Your body is only going to sleep for no more than 8 hours. I found myself sleeping the same amount, sometimes less.”
- “Schedule still dictates time available to sleep.”
- “Appointment times are middle of night and odd times.”

- “The HOS regs never affected my sleep.”
- “Because if you get the proper rest you drive better.”
- “Because I still have about 6 – 7 hours of sleep.”
- “Use to sleeping about 6 – 7 hours.”
- “Lifestyle hasn’t changed.”
- “I’m home every day and have the comfort of my own bed vs. a sleeper berth.”
- “LTL operations; home every day, weekends off.”
- “My work stays about the same all the time, same goes for my sleeping.”
- “Nothing as far as work habits changed.”
- “I don’t need much sleep anyway.”
- “A lot of times a driver is ready to go before the 10 hours are up and we’re not kids but trained as so.”
- “Habits, old habits are hard to change.”
- “Because of my schedule.”
- “The changes didn’t affect local drivers too much.”
- “I always get my sleep in.”

<u>I get more sleep under the revised</u> hours-of-service regulations (after January 4, 2004)

- “Sometimes I have to stay 2 hours longer than if I had 8 hours of rest.”
- “I get 10 hours off time.”
- “Gives me a chance to slow down before I go to sleep.”
- “I think because it took at least one hour to wind down to sleep and had to plan on getting up 1 hour before my next scheduled drive time there by losing 2 hours of sleep.”
- “Puts more time not to be wasted.”
- “More time to sit and have nothing to do.”
- “More hours off.”
- “More restricted.”
- “But I cannot make that much money.”
- “I feel more alert and less tired.”
- “Most of my loads give me enough time to stop and nap if I need to.”
- “Because of revised 14 hour rule, does not let your work day go over 14 hours unless you have sleeper berth time.”
- “More hours to work and/or rest.”
- “More time off to sleep.”
- “More time.”
- “In my situation, 10 hours off allows better sleep time.”
- “I have more time to do so.”
- “The extra 2 hours help me get back to sleep to finish my night.”
- “More required rest time.”

Question 7:
How do you think your **quality** of sleep (how well you sleep at night) now compares to the quality of sleep that you got under the old hours-of-service regulations (before January 4, 2004)?

<u>I sleep better under the revised</u> hours-of-service regulations (after January 4, 2004)
- "When you work more, you're likely to sleep more."
- "The 14 hour rule limits how much I can stretch my day."
- "No pressure to get the 10 hours in under the old regs."
- "I have more time to relax."
- "Have more time to sleep."
- "I can lay down knowing I can sleep for at least 9 consecutive hours."
- "Better sleep because more hours off."
- "Under the old rules I still felt tired."
- "Work divided more evenly between day/night. Not as broken up as under old rules."
- "More time off to sleep."
- "In my situation, 10 hours off allows better sleep time."
- "I'm not in so much of a rush."

<u>I sleep the same</u> now as I did under the old hours-of-service regulations
- "I only need 6 – 7 hour of sleep. Now I can stand around for an extra 3 hours waiting to go back on duty."
- "I still get in bed at the same time."
- "My sleep quality I have found was subject to everyday life stress, not the amount of time I have to sleep."
- "I still somewhat twist and turn."
- "Same amount of hours, more down time."
- "It did not change the way I sleep."
- "Always home by 8am, in bed by 9am."
- "I allow myself to get the sleep I need, I know what I need to do the job safely."
- "I have a set regulation hours-of-duty."
- "Nothing changed."
- "Don't know."
- "Because I trained my body to go on 8 hours; hard to sleep longer."
- "I do sleep the same way I did on the old HOS."
- "Before you can go to sleep any time or after finishing your duty, but now whether you have finished or not you time not but now soon you finish 14 hour from time you went on duty."
- "Noises still interrupt it."
- "The HOS regs never affected my sleep time."
- "Because I get my rest properly each night."
- "Because I still have about 6 – 7 hours of sleep."
- "6 – 8 hours is all I sleep."

- “You can get more sleep under new rules.”
- “Because I schedule my sleep.”
- “Nothing as far as work habits changed.”
- “Habits.”
- “When I get tired I stop and get my sleep.”
- “The changes didn’t affect local drivers too much.”
- “When I go to sleep, I sleep hard.”
- “I never used old one because I was a local driver before JB Hunt.”
- “I think I’m going to sleep too long.”
- “Sleep is sleep.”
- “Ten hours is too long to be sitting.”
- “Because I don’t get that much tired.”

<u>I slept better under the old</u> hours-of-service regulations (before January 4, 2004)

- “Because the 14 hour rules was not there.”
- “I could sleep when I wanted to and not mess up my log book.”
- “I was tired when I shut down.”
- “Because you could run after 8 hours; split earlier than 10 hours, you lose 8 hours in 2 days.”
- “Less hour of driving.”

Question 8:
Which do you like better:

Old hours-of-service regulations (before January 4, 2004)

- “The 14 hour rule is impractical when applied to the split sleeper option.”
- “Old hours gave me more work hours to earn more money.”
- “I like the 34 hour restart but don’t like the 14 hour rule”
- “Easier if you’re doing short runs.”
- “Because you do not have as many dead hours.”
- “Able to run more miles.”
- “Because of the flexibility of breaks, unlimited break time.”
- “Easier to follow”
- “You can get up and go.”
- “10 hours off is too long.”
- “When you take a break whether its off-duty or in the sleeper, it shouldn’t be used against 14 hour rule.”
- “The ability to reset hours more frequently.”
- “8 hours instead of 10 hours is the reason.”
- “Don’t like sitting for 10 hours.”
- “Could run more.”
- “More flexibility.”
- “You could divide your time better.”

- “More flexible.”
- “More sensible.”
- “But have the restart after 34 hours off on the new, why because I can be further down the road in 8 hour break than 10 hours.”

Revised hours-of-service regulations (after January 4, 2004)

- “The amount of hours you get now to drive. “
- “11 hour of driving, 10 hour break; though the 14 hour rule is disagreed.”
- “Can get more sleep; can reset 70 hours.”
- “I feel a lot better after a break; more rested and alert. I feel more healthy.”
- “More time off and better sleep per day.”
- “Get more sleep plus you get to restart your hours after taking 34 off.”
- “Better sleep.”
- “More drive time, and also like the split.”
- “To me if you plan it right, there is much more time to do what is needed to do.”
- “You reset 70; 11 hour drive time.”
- “You’re not as pushed for the 10 hour driving rule you have an extra hour.”
- “It provides both more time to sleep and drive.”
- “I like the 34 hour reset.”
- “I like them both but I like the 34 hour restart.”
- “You can pick up 70 hours after having 2 days off, easy to keep and track logs.”
- “The revised hours allow you to rest more and you also know other drivers that share the road are getting theirs, as long as they follow the HOS rules.”
- “We can run longer hours.”
- “Run more miles.”
- “One more hour to drive.”
- “Because it resets its 70 hours after the 34 hours of break.”
- “34 hour restart.”
- “14 hour days are shorter than 16 hour days if followed.”
- “You can do more with a shorter time off (34 hour reset).”
- “More time to drive in a day.”
- “34 hour restart.”
- “More miles per day, more off time per day.”
- “More time off before having to go back out and being able to start your 70 hours after 34 hours off.”
- “Puts emphasis on total amount of working and driving hours allowed.”
- “It works better for our type of work.”
- “Better way to plan your day.”
- “I like the restart.”
- “The additional hour of driving helps when you need it to make your destination. The additional 2 hours help when you can’t fall asleep right away, you then have 8 hours instead of 6 hours to rest.”
- “We begin 70 hours after 34 off; 1 more hour to complete an otherwise 10 hour run.”

- "11 hours drive time and 34 hour reset."
- "More driving hours and on-duty hours."
- "34 hour break start with a new 70."
- "Because the company won't keep driver who wanna go home out there."
- "34 hour restart."
- "70 hour workweek is reset after 34 hour consecutive off duty."

Drivers who did not select one of the two choices but answered the 'why' section

- "It doesn't matter much."
- "It does not affect our company that I know of. I would think it has hurt other companies."

Drivers who selected both of the two choices

- "Change did not affect me."
- "They both have pros and cons."

Question 9:

If you could change anything about the revised hours-of-service regulations, what would it be? (Please take a minute to answer this question…this is a chance to voice your opinion on this important issue.)

- "Change did not affect me."
- "Change the total of hours that you can be on duty back to at least 15 hours."
- "With 11 hours of driving a day, by the 5th day I'm getting close to my 70, so I think they should increase 70 to 80."
- "No change."
- "Nothing."
- "Everything is fine."
- "I like it just the way it is. I have been driving for over 5 years and I think it is a great change."
- "I would increase total day hours from 14 to 15 to allow for circumstances that arise."
- "Change the 10 hour break rule to 8 hours."
- "Nothing because I'm somewhat new to the industry, so I didn't work under the old regs but it seems like this way we get no of a break, but less of a sit down to get back to working again."
- "I don't think you need ten hours break. I would go back to 8 hour break and keep everything else the same."
- "I would go back to the old way but keep the 34 hour rules. Because when the next week begins I have 70 hours to run and be product for the company."
- "The same as it is now."
- "To be able to start your day and stop it and it not affect your hours."
- "The revised hours is good but the customers making it hard for drivers to follow since sometimes they let drivers sit for long time for load. Driver need to feed their family so sometimes they cheat."

- “I would do away with the 14th hour rule; go back to 15 hours on duty and not count sleep time and off duty towards 14 hours.”
- “Go back to the old hours, drivers are not sleeping that much. They still drive the same amount of hours anyway. No one needs to drive ten "hours".”
- “There is not much you can change, it is alright.”
- “Change the 14 hour work day, extend with off-duty time.”
- “Very satisfied with HOS; all times need to match and easy to keep logs with picking up 70 hours after 2 days off.”
- “I think the revised HOS has been well thought through, it is there for the drivers and the people we share the roads with. It cuts down on trying to push your body to the limit, and if everyone follows the rules it will be safer highways.”
- “Nothing.”
- “Let us take naps and stop the clock.”
- “Hold companies more responsible for ensuring regulations are adhered to instead of pushing drivers, or trying to influence drivers to break the rules; set reasonable delivery times according to regulations time restraints and speed limits.”
- “I would not change nothing; I like it.”
- “Change the 14 hour rule and keep the rest the same.”
- “I like the new rules just the way they are. Because at least my loads work out. The new rules are very easy to work with and stay in compliance.”
- “A only truck lane.”
- “It would only take 24 hours for a restart.”
- “The old HOS rules were fine. The new HOS rules make it easier to cheat.”
- “The 14 hour rule limits me, increase to 16 hour.”
- “Change driving hours from 11 to 12 or 13.”
- “I would change the 14 hour rule. Can't be on duty more than 14 hours whether driving, off duty, or on duty not driving. It takes away from driver able to get miles. I like the 34 hour reset.”
- “Time for a nap without counting against hours.”
- “Off duty time against 14 hour. If off duty time doesn't count against your 14 hours, drivers would take break whenever they feel not safe to operate the vehicle. But now people are forced to drive even if they are not safe to do so because of the off duty.”
- “There's really nothing I would change, except the split driving rule. If you can combine sleeper berths why can't you drive for 11 hours instead of what you have left of your 11 hours.”
- “I would have GPS systems installed on all trucks accessible to the DOT. To keep everyone honest. This is the only way to prevent creative logging.”
- “I personally think that this is the best that we have had it, I wouldn't change anything.”
- “The 14 hour rule in conjunction with the split sleeper. I rarely have a day without a break between sleeper berths, so the 14 hour rule limits the practical usefulness of the extended day.”

- “* Put it back to 15 hours/day
  * 8 hour break
  * I do like the 34 hour go back to 70 rule”
- “I wouldn't change the revised HOS, I think they're a lot better.”
- “The new hours are, I like the 34 hour reset. It really helps.”
- “* More driving time
  * Less on-duty non-driving time
  * 40 hour restart instead of 34 hour restart
  * 8 hour break instead of 10 hour break”
- “Nothing.”
- “Go back to 8-hour sleeper to off-duty period.”
- “Go back to 8-hour, that is enough sleep and should be rested.”
- “None.”
- “I would split hours in an even 3-way split; 8on, 8off, 8on so a person could work a double shift and earn more.”
- “I never drive OTR, so for me it doesn't have much impact. But, if I could pick, I would stay with the revised hours because of the 34 hour rule.”
- “I would implement the "14/10 driver discretionary rule"…14 hours on duty - driving and working or just driving or just working. And, a ten hour break that could be split upon drivers discretion.”
- “I wouldn't change a thing about it. I like it very well now.”
- “I think the hours of service are unrealistic compared to other industries. The trucking industry is regulated a great deal more than other careers. It is about revenue period. This is coming from a former police officer. I know the stigma trucking has.”
- “N/A.”
- “I would like to drive to I get tired and sleep when I need it not when to sleep.”
- “The type of job that I have the revised hours work just fine being off duty on the week end gives me the 34 hours plus a fresh 70 hours on Monday.”
- “The HOS old or new really hasn't changed anything concerning my work.”
- “No regs at all.”
- “Drive 11 hours, sleep 8.”
- “1 hour off the clock for meals.”
- “* Give us back our meal breaks - the ability to "stop" the 14 hour clock by going to off duty (line 1)
  * Go back to 8 hours off to reset the tour of duty
  * Keep 34 hour reset
  * Require all truck, and cars, to have on-board recording devices. This is the only way to enforce log book rules.”
- “8 hours instead of 10 hours off, no make up hours for break.”
- “8 hour sleeper berth time instead of 10. It is obvious shippers are not willing to cooperate with the trucking industry to cut down on driver waiting time. This cuts down on hours you can actually drive reducing driver wages and company profits.”

- “I think if a driver could drive 10 hour and take hours rest as he needs it as long as he didn't drive more than the 10 hours without rest.”
- “A break is a break. Line 1 off-duty and 2 sleeper berth shouldn't be used against you or 14 hour rule.”
- “Need more enforcement.”
- “I think the revised system works perfect, although I am a local driver that works only Mon - Fri, I can still realize the benefits of the new system.”
- “Put old HOS rules into effect with 34 hour restart provisions.”
- “No change at this time.”
- “It's fine.”
- “The thing that I would like to change is the manner of splitting your log. To me you should not have to show being in the b week to split your logs, and your breaks should not (to a degree) be part of your hours on duty.”
- “* Get rid of 14 hour rule.
  * Let us use line one to not count against our driving day.
  * Let us drive 15 hours a day, every day.”
- “More on-duty hours.”
- “The 14 hour rule. I could keep driving safely even after 14 hours of work, with a 1 hour nap or shorter safely.”
- “If you have more than one two hour break in 24 hour period you should be able to use them toward sleeper berth not only the last one before you take your sleeper break.”
- “Do away with the 14 hour rule. Let me work or drive my 14 hours then rest for 10 hours, it's what we're doing out here any way.”
- “I wouldn't change anything.”
- “I just want to do my job.”