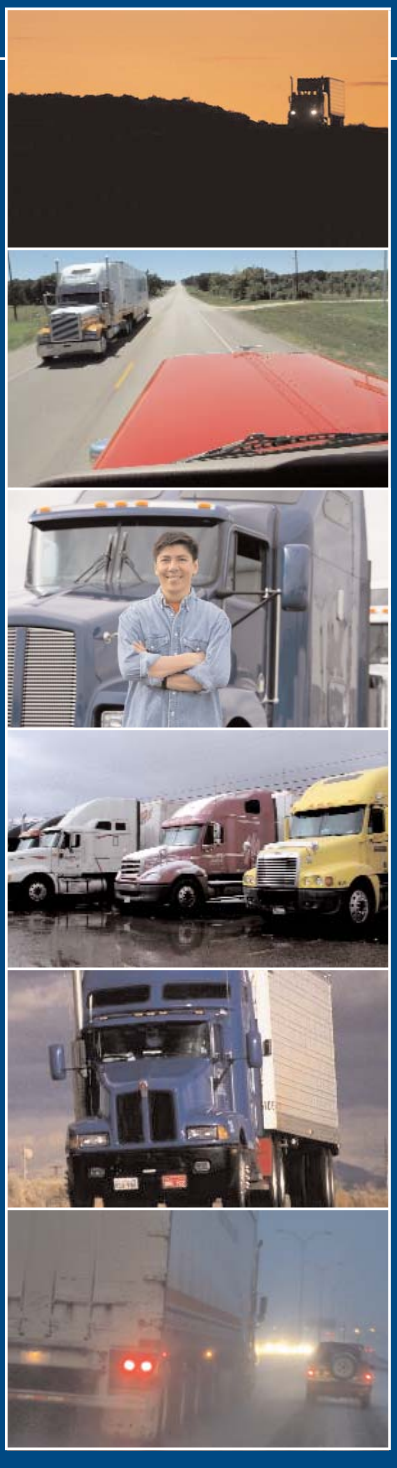
Consensus Between Circadian/Sleep Experts and Truck Drivers On the Impact of 2005 U.S. Federal Hours of Service Split-Sleep and 14-Hour Clock Regulations On Truck Driver Sleep and Alertness

I Martin Moore-Ede, M.D., Ph.D. I

Circadian International, Inc. Report



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However, any conclusions and opinions expressed are those of the authors and not necessarily the ATA.

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Executive Summary

The U.S. Federal Hours of Service regulations for heavy truck drivers have gone through a period of rapid change in the past three years driven by a court-order and regulatory agency initiatives. This study was designed to evaluate whether the resulting new features in the current Hours of Service regulations, including the split-sleep restrictions and 14-hour clock, are appropriately designed to meet their intended purpose of improving driver sleep and health, and driver alertness and safety on the road.

Because the recent changes have largely been driven by legal argument and regulatory agency interpretations of a complex body of circadian and sleep science, it is important to evaluate whether the outcome meets the intended objective. This study sought to determine whether a consensus could be found between two sources of expertise with diverse interests each well positioned to judge the impact of the current Hours of Service regulations: 1) circadian/sleep experts who have studied the sleep and alertness of truck drivers and other night workers, and have published peer-reviewed research on sleep, fatigue and accident risk, and 2) experienced truck drivers who use sleeper-berths on a regular basis.

A web-survey was constructed with twelve pairs of 2-3 day driving scenarios, one of which was strictly compliant with current Hours of Service regulations introduced on October 1, 2005 ("Compliant"), and the other which was non-compliant but potentially more circadian and sleep science friendly ("Non-Compliant"). Eleven internationally-recognized circadian/sleep experts, and 67 truck drivers with at least three years of driving experience in trucks equipped with sleeper-berths which they regularly used, independently took the survey. Each participant was required to select, and explain their choice of which trip duty-rest schedule from each scenario pair was most likely to provide for good quality sleep and enable sustained alertness and safe driving on the road.

Circadian/Sleep experts on 100% of occasions and truck drivers on 73% of occasions selected the Non-Compliant option as most likely to enable better sleep, alertness and safety. For the 10 out of 12 scenarios requiring at least 10 hours rest per day, on average 78% of truck drivers preferred the Non-Compliant option, but for the two options with less than 10 hours rest, drivers chose the Non-Compliant option on average on 48% of occasions. 100% of the Non-Compliant options were selected by at least some drivers, and the comments showed individual differences in sleep-wake physiology were an important part of the individual driver's choice of preferred scenario option.

These results support the conclusion that more flexibility is needed in the current Hours of Service regulations to allow drivers the option to select sleep times and lengths to suit their individual needs, and to ensure better alertness and safety on the highways.

Introduction

Ensuring that truck drivers obtain sufficient sleep, and keep alert when driving on the nation's public highways, is a vitally important objective for all stakeholders, including truck drivers, trucking companies, the American Trucking Associations (ATA), the general public, and regulatory agencies such as the Federal Motor Carrier Safety Administration (FMCSA) and the states. The widespread recognition of the importance of driver fatigue in the causation of highway accidents in both private passenger and commercial vehicles (Langlois et al, 1985, Horne & Reyner 1995, Mitler et al 1997), and the increasing volume of traffic on the nation's highways 24 hours a day, 7 days a week driven by the demands of the non-stop 24/7 economy (Moore-Ede 1993) has made addressing driver fatigue a national safety priority (FMCSA, 2000).

For commercial vehicle drivers, the main government regulatory initiative to combat the risk of driver fatigue has been the development, revision and enforcement of Hours of Service regulations (HoS). First implemented in 1937, these regulations sought to minimize the risk of driver fatigue and the adverse effects on driver health and safety by placing restrictions, both on a daily and a weekly basis, on the maximum number of hours on-duty and hours driven, and the minimum number of hours of rest.

Over the past 30 years, the limitations of this conceptually simple HoS paradigm have become increasingly clear as a result of advances in the science of driver fatigue and the mechanisms of sleep-wake, alertness & circadian physiology (Moore-Ede, 2002, Moore-Ede & Schlesinger 2004). Research findings on the importance of sleep duration, time since last sleep, and circadian (biological) time of day in determining driver fatigue risk, and the limits in the rate of adjustment of the sleep-wake cycle to changes in duty-rest schedules, led to the recognition that revisions of the HoS regulations would be necessary.

Proposals have been made over the past twenty years by various concerned parties to improve the HoS regulations so they better meet their intended objective of reducing driver fatigue and minimizing the impacts on driver health and safety. After much debate and consultation with circadian/sleep experts, drivers, trucking companies and other interested parties, attempts were made by the Federal Motor Carrier Safety Administration (FMCSA), to introduce new HoS regulations in 2000 but this attempt failed because of a lack of consensus on the optimal solution.

In the past three years, a court-ordered mandate and initiatives by the FMCSA have led to a series of changes in HoS. New HoS regulations first went into effect on January 4, 2004, but within a few months they were challenged and vacated in Federal Court, then

reinstated by Act of Congress for a temporary one year period. After a Notice of Proposed Rule Making (NPRM) which received over 1,800 comments, the regulations were revised again effective October 1st 2005, but are now subject to further challenge in the courts.

The key question addressed in this study is whether the recent court-ordered and regulatory agency-designed revisions have actually improved truck driver sleep, alertness and safety. Or have certain well-intentioned revisions to HoS, such as the latest split-sleep rules, and the 14-hour clock, had undesired effects on sleep, alertness and fatigue?

To answer this question, two independent and diverse groups each well-qualified to determine whether the duty-rest schedules enforced by current HoS are having the desired effect on driver sleep, alertness, safety and health were consulted. The first was a panel of internationally-recognized scientists in circadian physiology and sleep science who have published peer-reviewed research on sleep, circadian rhythms and alertness in truck drivers or other groups of night or shiftworkers (see Appendix A). The second group was truck drivers with more than three years experience of driving sleeper-berth equipped trucks under the various iterations of the HoS regulations, and who obtain their sleep in the sleeper-berth on some or all of their driving days (see Appendix B).

The thesis underlying the design of this study was that if we could find a consensus between these two well-qualified but diverse-interest expert groups, this should be a significant addition to the body of circadian sleep science, and its interplay with truck driving logistics.

Methodology

Design of Scenarios

Twelve trips were designed each with a fixed starting time, and a fixed deadline for completion of the trip. While on route any rest was taken in the sleeper-berth. Each trip was completed within 72 hours and did not exceed 60 hours driving in 7 days or 70 hours driving in 8 days.

For each of the 12 trips two driving scenarios were designed. One driving scenario was in strict compliance with the current (October 1, 2005) HoS regulations. It required a minimum of 10 hours rest (off-duty or sleeper-berth) before commencing driving and obeyed the 14-hour clock rule (no driving beyond the 14th hour after beginning duty after a 10-hour rest period), and the split-sleep rule (10 hours rest may only be split into two rest segments if one of the rest periods is at least 8 hours and the other is at least two hours). This set of driving scenarios options is referred to as “Compliant”.

The second driving scenario option for each trip was designed to allow the construction of duty, rest and driving patterns that enabled the strategic placing of naps and the timing of sleep so that they were more likely to promote alertness while driving. However achieving this goal caused violations of the split-sleep and 14-hour clock rules. This set of driving scenarios options is referred to as “Non-Compliant”.

Ten of the twelve Non-Compliant scenario options (#1, 2, 3, 5, 6, 7, 8, 10,11,12) limited on-duty time to a maximum of 14 hours per day, driving to 11 hours, and provided a minimum of 10 hours total rest per day. Two Non-Compliant scenario options (# 4 & 9) also permitted violations of the 10-hour total rest minimum, the 11-hour driving maximum and the 14-hours on duty maximum in order to maximize sleep opportunity at optimal times of night.

Figure 1 provides an example of a trip pair, with one Compliant and one Non-Compliant scenario option. The drivers are assumed to be fully rested having spent two days off duty and slept for 8 hours from 12 midnight to 8 AM on both nights (Day 1 and Day 2). Each scenario trip starts at 8 PM (20:00 hrs) on Day 2 and has a delivery deadline of 5 PM (17:00 hrs) two days later. For each scenario the total driving time was 22 hours, and the total on-duty time was 28 hours. Each scenario also provides for at least 10 hours of sleeper-berth or off-duty time per 24 hours. However the Compliant and Non-Compliant scenarios differ in the driver’s scheduling of sleeper-berth time.

The Compliant scenario (Scenario #1 Option A) strictly obeys the current (October 1, 2005) HoS regulations and its new split-sleep rules, which require a minimum of 8 hours of consecutive sleeper-berth or off-duty time, and is designed to encourage 10 hours of consecutive sleeper-berth time irrespective of the time of day it is taken. Furthermore, the current HoS 14-hour clock rule can discourage drivers from taking needed rest breaks after starting a trip, as it may cause them to run-out the 14-hour on-duty clock from the time of coming on duty, and thus not be able to deliver their load on time. Thus in the Compliant scenario option the driver goes on duty at 20.00 hrs and, after driving through the night, ends his duty 14 hours later at 10:00 hrs, (after driving 11 hours and being on-duty not-driving for 3 hours). He then takes his required 10-hour sleeper-berth rest period from 10:00 hours to 20:00 hours, before beginning driving again overnight in a duty period that runs from 20:00 hours to 10:00 hours.

Figure 1. Compliant and Non-Compliant Scenario Options

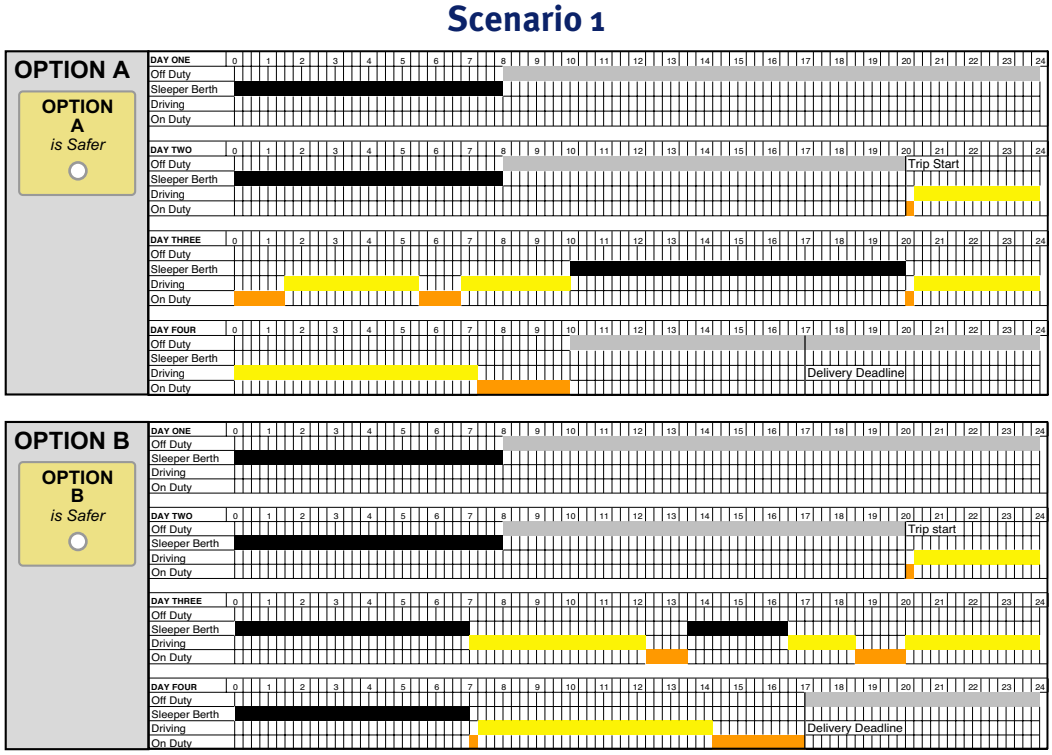

Figure 1: Example of a scenario option pair: Respondents were asked to choose either Option A (Compliant with current HoS) or Option B (Non-Compliant with current HoS) by considering which option would enable the best quality sleep and the greatest likelihood of sustained alertness while driving.

In the Non-Compliant scenario (Scenario #1 Option B) the driver disobeys the split-sleep and 14-hour clock rules in order to ensure that his sleep is taken at the same time every night. He also allows for an afternoon nap at the circadian phase most conducive to long recuperative naps (i.e. the "siesta hours"). As a result he goes on duty at 20:00 hours on Day 2 but stops to sleep for 7 hours in the sleeper-berth from 24:00 to 07:00 hrs. He then goes back on duty and drives from 07:00 to 12:15 hrs on Day 3, and then takes a three-hour break in the sleeper-berth from 13:30 to 16:30 hrs before getting back on the road and driving through to midnight with a non-driving on-duty break from 18:30 to 20:00 hrs. On Day 4 he is in the sleeper-berth from midnight to 7 AM before getting back into his truck cab and finishing the trip and delivery by the 17:00 hrs delivery deadline.

Had a police officer or DOT inspector inspected the Non-Compliant drivers log book he would have been ticketed for being in violation of the 14-hour clock rule at 10:01 hours on Day 3, and would also be in violation of the split-sleep rule at that time, and for the rest of the trip. These violations of the HoS regulations would not give any credit for the fact that the Non-Compliant driver was taking seven hours longer to complete the trip than the Compliant driver, with all those extra seven hours spent in the sleeper-berth at night.

The remaining eleven pairs of scenarios were similarly designed to reflect a wide variety of starting and ending times, and lengths of trip, with one option being strictly Compliant and the other Non-Compliant but potentially more circadian-sleep friendly. Each of the scenario pairs is provided in Appendix C to this report.

Initial Risk Assessment of Scenario Options

To test whether all the Non-Compliant trip scenarios we designed were "circadian/sleep friendly" – i.e. likely to offer drivers an improved opportunity to obtain good quality sleep and had a higher probability of promoting sustained alertness and safety, each Compliant and Non-Compliant scenario was first assessed using a validated[1] software model of truck driver fatigue risk, the Circadian Alertness Simulator (CAS). CAS Fatigue Risk Scores have been shown to be well correlated with truck driver alertness and the risk of DOT recordable truck accidents (Moore-Ede et al 2004) , and are regularly used to assess the fatigue risk of trucking fleets and to plan dispatches and schedules to minimize truck driver fatigue risk, injuries and accidents (Moore-Ede et al 2005).

1 *CAS has been validated 1) in peer-reviewed published retrospective studies correlating CAS fatigue scores with DOT recordable accident rates, 2) peer-reviewed published prospective studies of accident rates and injuries per 200,000 hours where duty-rest schedules have been adjusted to minimize CAS fatigue scores, and 3) in double-blind studies independently conducted by trucking fleets which assessed the ability of CAS to predict the risk of preventable accidents amongst their drivers.*

Table 1. Initial Risk Assessment of Scenario Options

Scenario Number	Compliant Options		Scenario Number	Not Compliant Option	
	Fatigue Score	% Time In Red		Fatigue Score	% Time In Red
1	68.4	10.4%	1	12.6	0.2%
2	44.4	6.2%	2	4.9	0.5%
3	47.8	7.1%	3	4.1	0.5%
4	49.0	4.1%	4	19.2	0.0%
5	77.8	14.1%	5	50.1	4.9%
6	81.1	12.5%	6	58.1	6.8%
7	69.8	5.8%	7	25.0	0.4%
8	58.1	3.6%	8	17.5	0.8%
9	83.0	13.9%	9	54.0	3.2%
10	57.6	8.8%	10	29.3	3.6%
11	58.8	7.9%	11	11.6	0.0%
12	53.6	3.5%	12	21.5	1.2%
MEAN	**62.5**	**8.2%**	**MEAN**	**25.6**	**1.8%**

Table 1: Initial Risk Assessment of Scenario Options. The Circadian Alertness Simulator (CAS) was used to assess chronic fatigue risk (Fatigue Score 1= minimum risk, 100 = maximum risk), and percentage time of total driving hours where there was an increased probability of driver lapses in alertness (% Time in Red) for each of the scenario options that were designed for this study.

The Fatigue Risk Scores (0=lowest risk, 100=highest risk) for each set of Compliant (right) and Non-Compliant (left) scenario options are shown in Table 1. The mean CAS Fatigue Risk Score for the Compliant Options was 62.4 and for the Non-Compliant options was 25.6.

Although there was some overlap between the two sets of scenarios, each Non-Compliant option was left shifted (lower Fatigue Risk Scores) from its Compliant alternative by an average of 36 points on the CAS Fatigue Risk Scale.

Table 1 also shows the percentage of the total hours while on duty spent in the CAS red zone where there is a heightened probability of a fatigue-related accident (Moore-Ede, 1993, 2002). In the Compliant options the average time in the red zone was 8.2%, and in the Non-Compliant options the average time in the red zone was 1.8%. This preliminary analysis thus confirmed by CAS simulation that the Non-Compliant options were more circadian/sleep friendly than the Compliant options.

Design of Web-Based Survey

To standardize the presentation of the scenario options and collection of data for all respondents, whether they were circadian/sleep experts from various locations in the USA and internationally, or truck drivers located in various states across the USA, a web-based survey was designed and uploaded onto a password controlled website. Once a user's identity was confirmed by user name and password, the survey first collected personal identification information and biographical data on the respondents' relevant experience to enable determination of the users qualifications either as a circadian/sleep expert, or as a long-haul truck driver. For the circadian/sleep experts a full academic curriculum vitae and publications list was collected to document relevant research experience. For drivers the length and details of their experience in truck driving, and the type of operation they worked for was obtained.

Once this qualifying information was collected to ensure each respondent met the required criteria, an explanation of the scenario options with an illustration was provided. Each respondent was asked to select the scenario options most likely to enable drivers to obtain recuperative sleep, and to maintain alertness, and safe driving on the road. To ensure this was the primary rationale for their option selection, and to understand their reasoning each respondent was required to provide a brief explanation for their choice.

The web survey was set up on a series of web pages with controlled access so that the next page in the sequence could not be accessed until the respondent had provided all the required information on the current page. Only the data from fully completed surveys were transmitted into a confidential database. This database could only be accessed by the CIRCADIAN staff managing this study. Progress in receiving completed surveys was reviewed on a daily basis, but none of the individual results was seen or reviewed by anyone other than the CIRCADIAN project team.

All participants (circadian/sleep experts, and truck drivers) were kept completely blind to any of the results obtained from the other participants, and also blind to the results of the CAS simulation.

Beta Testing of Web Survey

To ensure the operation and instructions of the website were readily understandable to the user and that the data was accurately collected in the confidential database, eleven truck drivers were recruited to complete the survey and provide any comments and suggestions. Each of the truck drivers was paid an honorarium of $50 to complete the web survey and provide their feedback. The beta test demonstrated that the web survey functioned smoothly. As a result of the beta test, no changes were made to the scenario options or the presentation of data and instructions to the users. The only changes were made in the mechanics of data upload into the confidential database.

Recruitment of Circadian/Sleep Experts

There has been a considerable body of research published over the past 25 years in the international scientific literature on the factors which influence the sleep, alertness and safe driving performance of truck drivers and other people who work extended, irregular or nocturnal hours. To ensure that the scenarios were evaluated by taking into account the broad body of scientific literature, we invited leading experts in sleep and circadian rhythms who had a significant track record of published relevant research in peer-reviewed journals to participate. Eleven internationally-recognized scientists accepted the invitation, and their names, positions and affiliations are listed in Appendix A. Each was given a unique User Name and Password to access the website.

Each circadian/sleep expert independently took the web-based survey; and they were not informed of the answers given by the other experts or the drivers. They were each compensated for their time in taking the survey.

Recruitment of Drivers

We established as criteria for the recruitment of drivers that they should:

1. Have at least three years experience of driving trucks with sleeper-berths, so that they had experience operating under pre-2003 HoS rules, the revised rules implemented on January 4th 2004, and the modifications implemented on October 1st 2005.
2. Drive in long-haul operations either nationally or regionally.
3. Utilize a sleeper-berth for some or all of their rest periods.

Methodology

To recruit drivers we announced the study to the members of the American Trucking Associations (ATA) Hours of Service Subcommittee, and requested their help in recruiting drivers from their companies who met the above criteria. Ten companies ranging from the Top 10 largest fleets to smaller carriers with 100-200 drivers volunteered their help in recruiting drivers. Each company appointed a local manager to be the contact point for drivers. Each prospective driver volunteer was given a standard letter explaining the purpose of the study, and was issued with a unique User Name and Password to access the website. The drivers independently accessed this web survey website from their homes, truck stops, or their terminals.

A total of 74 truck drivers completed the web survey. 67 of them (59 men, 8 women) were determined to be qualified according to the criteria listed above. Seven respondents were disqualified either because they had less than 3 years of truck driving experience (3 drivers) or did not regularly use a truck sleeper-berth to sleep (4 drivers). No driver was disqualified based on their choice of scenario option, or their answers explaining the rationale behind their choice. The participating drivers' homes were located in 19 different states in all regions of the USA, although most of them were driving trucks, and using their sleeper-berths, on a regular basis on nationwide routes.

Eleven of the 67 participants were participants in the beta test and were therefore compensated. The remaining 56 drivers were not compensated for their participation. An analysis of the data collected from the 11 compensated drivers and the 56 uncompensated drivers revealed no significant differences in their responses, and so both groups were combined into the total 67 qualified driver data set.

Data Analysis

The data collected in the confidential web server database was exported into an Excel spreadsheet for statistical analysis. The responses to the qualification questions were first reviewed to select the drivers and circadian/sleep experts who were qualified according to the pre-set criteria. The non-qualified respondent data was excluded from the data set prior to group analysis.

Circadian/Sleep Experts

For all twelve of the driving scenarios the circadian/sleep experts all selected the Non-Compliant options as being more conducive to driver sleep and alertness on the road than the corresponding HoS Compliant alternative options (Table 2). The experts' comments on the survey indicated they based their opinions on their knowledge of the extensive body of scientific research literature on circadian rhythms, sleep and alertness and its impact on the average truck driver's health and safety.

Table 2. Scenario Option Selections by Circadian/Sleep Experts and Truck Drivers

Scenario Number	CIRCADIAN/SLEEP EXPERTS	TRUCK DRIVERS
	Percent Selecting Non-Compliant Options	Percent Selecting Non-Compliant Options
1	100%	78%
2	100%	72%
3	100%	88%
4	100%	33%
5	100%	78%
6	100%	78%
7	100%	84%
8	100%	66%
9	100%	64%
10	100%	79%
11	100%	78%
12	100%	76%

Table 2: Percent of respondents selecting the Non-Compliant scenario option as preferable to the strictly HoS Compliant option in terms of promotion of good quality sleep and alertness and safety while driving. The Non-Compliant option in Scenarios 1, 2, 3, 5, 6, 7, 8, 10, 11 & 12 violated only the split-sleep and 14-hour running clock provisions of the current HoS regulations. Scenario options 4 & 9 also permitted violations of the 10-hour rest, 14-hour on duty and 11-hour driving rules.

Truck Drivers

The truck driver responses are also indicated in Table 2. For all scenario pairs, except for #4, the majority (64-88%) of truck drivers preferred the Non-Compliant option. For example for scenario #1, presented in Figure 1 above, 78% of drivers chose the Non-Compliant option as preferable over the Compliant option in terms of enabling better sleep, alertness while on duty, health and safe driving. This was despite the fact that the Compliant option allowed them to return home seven hours earlier than the Non-Compliant option.

For the ten Non-Compliant schedule options where the only HoS violations were the split-sleep rules and the 14-hour clock (#1, 2, 3, 5, 6, 7, 8, 10, 11, 12), an average of 78% of the drivers preferred the Non-Compliant option. However for the two options where less than 10 hours rest or more than 14 hours on-duty was permitted (4 & 9), fewer drivers (average 48%) chose the Non-Compliant option.

In scenario #4, only 33% of the drivers preferred the Non-Compliant option over the Compliant option, and the drivers comments indicated that this was because they regarded the amount of driving in the Non-Compliant option spread over a 17-hour work day was too long. In scenario # 9 however, the majority (64%) still preferred the Non-Compliant option even though it had one extended day of duty and driving.

Figure 2.
Total Number of Non-Compliant Scenario Options Selected by Each Truck Driver

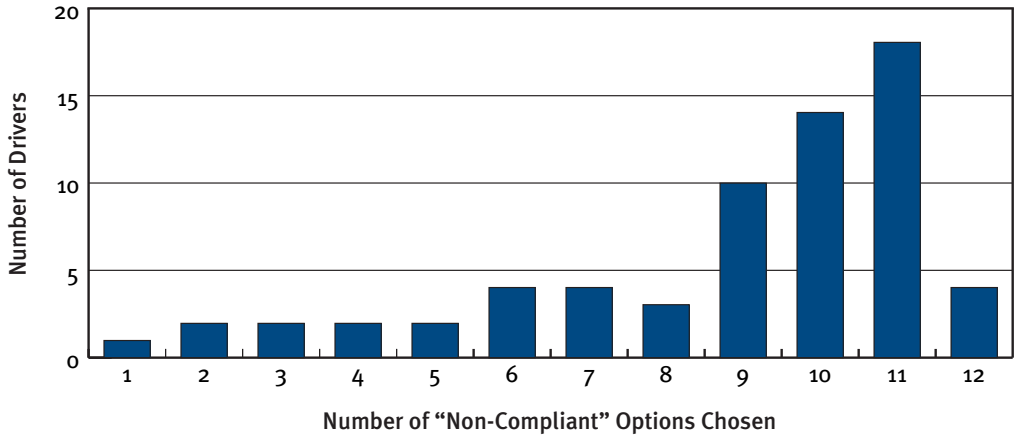

Figure 2: Number of Non-Compliant Options selected by Truck Drivers; All drivers picked at least one Non-Compliant option, and the majority selected at least half of the Non-Compliant options as preferable.

Overall the drivers chose the Non-Compliant option on 73% of occasions. When scenario #4 and #9 were excluded, the drivers preferred the Non-Compliant option over the Compliant option on 78% of occasions. All drivers preferred at least some of the Non-Compliant scenarios options over the Compliant option, and 57 out of 67 drivers (85%) chose the Non-Compliant option on at least 50% of occasions.

The comments of the truck drivers on the survey indicated that they each based their answers in part on their awareness of their own individual optimal sleep-wake patterns, which differed somewhat between drivers. Thus some drivers clearly preferred to sleep in the early evening and night, while others preferred a more delayed sleep phase.

Consensus Between Circadian/Sleep Experts and Truck Drivers

In Figure 3 the responses of the circadian/sleep experts are indicated by the light blue vertical bars, and the truck driver responses are indicated by the dark blue bars. In eleven of the twelve scenario choices, the majority of both the circadian/sleep experts and the truck drivers were in consensus that the Non-Compliant option enabled better sleep, alertness, health and safe driving than the strictly HoS Compliant option.

Figure 3. Comparison of Circadian/Sleep Expert and Truck Driver Responses to Survey of HOS Scenario Options

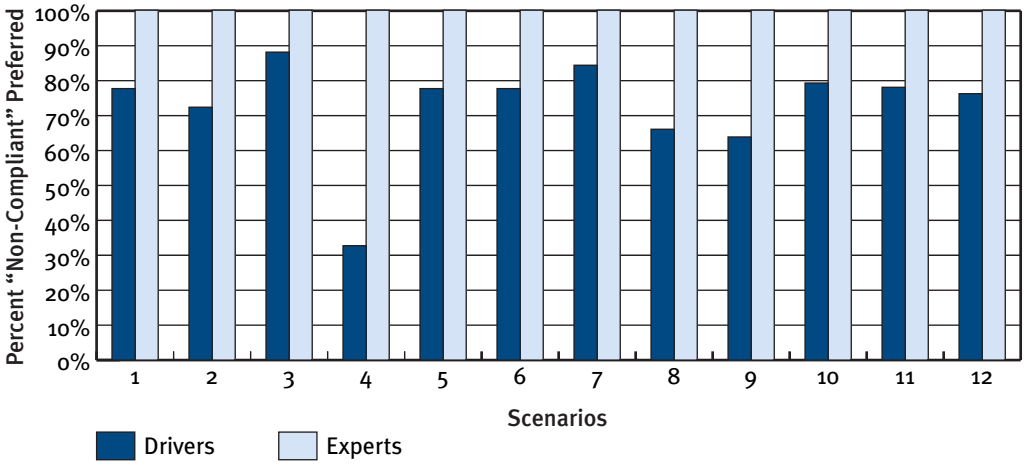

Figure 3: Percentage of truck drivers (dark blue) and circadian/sleep experts (light blue) selecting the Non-Compliant option as most likely to ensure adequate sleep and to sustain alertness while driving.

Results

In scenario #4 the circadian/sleep experts favored the Non-Compliant option because it allowed for more nocturnal sleep. For the majority of truck drivers however the length of Day 2 (17 hours from initial on-duty to final off-duty) and the amount of driving (15 hours) was too long.

Especially after taking into account that the individual drivers' responses were based in part on their knowledge of their own physiological characteristics, whereas the circadian/sleep experts had to respond without any knowledge of the drivers' individual circadian/sleep characteristics, there was a strong consensus that the Non-Compliant option was preferable over the Compliant option in 11 of the12 scenarios. This consensus was especially strong in the ten scenarios where only the split-sleep and 14-hour clock rules of the current HoS regulations were violated.

Discussion

It is vital to ensure that public policy, and federal and state regulations are correctly designed to minimize the risk of truck driving accidents caused by driver fatigue impairment. Unlike many other industries with safety-sensitive operations, trucks operate only a few feet away from the general public in carrying out their vital mission of delivering goods to support the nation's 24/7 economy. Although substantial progress has been made in reducing the rate of truck-related accidents per million miles, the average annual toll of deaths and serious injuries involving heavy trucks has kept national attention on the issue of truck safety, even though in truck-related serious accidents the fault has been shown to be more often that of the other driver involved in the accident than the truck driver (FMCSA, 2006, Hanowski et al, 2007).

The basis for change has come out of the substantial body of published research on sleep, alertness and circadian physiology and fatigue impairment over the past 25 years (currently running at over 8,000 scientific publications per year[2]), which has radically revised the concepts underlying driver fatigue from the accepted paradigms in the 1930's when HoS regulations were first designed and introduced.

A court-ordered change and regulatory agency initiatives over the past three years have resulted in a current set of HoS rules (effective October 1st 2005) which, when compared to the rules in effect before 2004, increases the minimum consecutive rest period from 8 to 10 hours, reduces the maximum on-duty time from 15 to 14 hours, prevents driving after the 14th hour of coming on duty ("14-hour clock"), increases the maximum driving time from 10 to 11 hours, and significantly constrains the ability of drivers to split their rest period into two or more "split-sleep" rest periods. The intended aim, and the widely-accepted result, has been to significantly restrict the flexibility allowed to the individual truck driver to choose when to sleep and when to drive.

While some drivers have supported the new rules, many solo and team long-haul truck drivers who use sleeper cabs to split their sleep have complained that the new rules force them to try to sleep when they are not tired, and discourage them from resting when they are tired (an example of one such driver's colorful opinion is provided in Appendix D). At the same time suits have been filed in the courts seeking even greater restrictions on driver sleep flexibility (McNally, 2006).

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2 *A search of PubMed, the National Library of Medicine's biomedical literature search engine for scientific articles, citing sleep OR alertness OR fatigue OR circadian, indicated that 24,515 scientific publications were published in the years 2004-2006, thus averaging 8,171 per year.*

Discussion

With the latest iteration of the HoS regulations (effective October 1st 2005) implemented for approximately a year it was important to ask the key questions addressed in this study:

- Have all the recent court-ordered and regulatory agency-designed revisions improved truck driver sleep, alertness and safety?
- Or have certain well-intentioned revisions to the HoS, such as the latest split-sleep rules, and the 14-hour clock, had negative effects on sleep, alertness and fatigue?

If the answers to these questions should show that the current HoS regulations had a negative impact on sleep, driver alertness and safety, it was essential to collect this information as efficiently and quickly as possible to ensure any harmful effects of the regulatory initiatives could be reversed. The alternative of commissioning a multi-year data collection study might result in unnecessary loss of life and injuries on the highways, and negative effects on drivers' health and safety, if the data took too long to gather and analyze.

When advocacy is passionate, and the safety of the public is at stake, it is especially important to ensure that the underlying science is correctly interpreted, and that the day to day experience of truck drivers operating under the HoS rules is taken into consideration. The specific revisions to the HoS regulations have been justified by the FMCSA in extensive documentation in the Federal Register which broadly cites the scientific literature, and the various advocates in lawsuits and petitions also cite articles from the extensive body of scientific research to support their often diverse arguments. The problem appears to be that these scientific issues were not adequately researched or understood.

Expertise and Potential Sources of Bias

The chosen methodology was to seek an evaluation of the current HoS from two groups especially well qualified to judge the impact of the HoS on driver sleep, alertness, safety and health, but who had diverse interests and non-complementary sources of potential bias.

Truck drivers who have operated trucks equipped with sleeper-berths and use them to obtain their sleep on a regular basis over the past three consecutive years are directly knowledgeable about the impact of the current HoS rules on their sleep and alertness through their day-to-day personal experience of the realities of trucking operations and trucker lifestyle. Potential sources of bias are that they often make a living through pay

systems that compensate them per mile or per load delivered, and their interest in getting back home to spend as much time as possible with their families. These sources of bias were minimized by ensuring that each driver explained their reasoning for their choices of scenario option by explaining each choice in terms of its impact on their sleep, alertness, health and safety.

Internationally-recognized circadian/sleep experts working at leading universities and research institutions who have 20 or more years of peer-reviewed research and publications, and have undertaken research on sleep and alertness in truck drivers and/or similar round-the-clock employee groups, are directly knowledgeable of the complexities of circadian and sleep science and its application to transportation fatigue risk. Potential sources of bias are that their research is dependent on generating ongoing funding from Federal agencies, companies and other interest groups, that funding for more research requires identifying and advocating problems to be solved, and that they may have provided consulting, legal expert witness or other support to one or more of these groups. To counter these potential sources of bias four of the eleven circadian/sleep experts were recruited from Australia, Sweden, France and England and therefore were largely disinterested in US funding sources and politics, and all experts, like the drivers, were required to explain their reasoning for their choices of scenario option in terms of sleep, alertness, health and safety science.

Any consensus found between these two groups addresses many of the expertise and potential bias issues. Where truck drivers might understate fatigue risk, sleep researchers might overstate it. Where truck drivers might understate effects on health and safety, sleep experts might overstate it. Where truck drivers subjectively assess fatigue, scientists objectively assess it. Where sleep experts might not be familiar with the day to day operations of trucking fleets, drivers are intimately familiar. Where truckers might not know the scientific literature, sleep experts are very familiar with it.

Establishment of a Consensus

For 11 leading internationally-recognized circadian/sleep experts to unanimously agree on their choices of all scenario options demonstrates that the past 25 years of research on sleep, circadian rhythms and driver fatigue has created a broad accepted consensus of established science on the key work-rest schedule related determinants of driver sleepiness and alertness. This aspect of this field of research is no longer “emerging” by the legal definition, and while there is much ongoing progress in certain parts of the field, such as in

the molecular biology of sleep and circadian rhythms, the core circadian sleep-wake cycle principles which are relevant to the choice of hours of work and rest are well established.

Overall the participating truck drivers agreed in 11 of the 12 scenario options with the scientific circadian/sleep experts. Setting aside scenario 4 & 9 which we discuss separately below, 78% of driver choices were for the Non-Compliant option which the circadian sleep scientists selected.

A skeptic might ask why didn't the drivers agree with the circadian/sleep experts 100% instead of 78% of the time, if this science is so well established? The reason is that the drivers had one more critical piece of information which the circadian/sleep experts did not have – the driver's own individual genetically determined sleep/circadian characteristics. Research on the genetic determinants of individual sleep-wake patterns has identified the genetics for such traits as morningness-eveningness (Katzenberg et al, 1998), optimal sleep duration napping propensity and flexibility/rigidity which determine each individual's preferred times and patterns of sleep, napping and alert optimal performance. The written responses of the drivers showed they used information about their own individual physiology (without fully understanding the science behind it) in their personal selection of scenario options. The circadian/sleep experts were not privy to this information and had to respond based on their estimate of the physiology of the average driver.

While the main purpose of the study was to test the validity of the current HoS split-sleep and 14-hour clock rules, we did include two Non-Compliant scenarios (# 4 & 9) where the 10-hour minimum rest, 11-hour maximum driving, and 14-hour maximum total on-duty rules were also violated. Even despite this, 100% of the circadian/sleep experts chose the Non-Compliant option. Their comments indicated that neither option was an ideal choice, but the Non-Compliant option was the better of the two options with respect to sleep and alertness, especially since there was only one extended day of duty and driving, and this was in drivers who were well rested before that day started.

For drivers, despite the better nocturnal sleep opportunity that the Non-Compliant options in scenarios 4 & 9 provided, the total amount of driving and length on duty were a significant issue. These two options garnered the fewest driver selections (48% on average) indicating that the main problem with the current HoS regulations are the split-sleep and 14-hour clock rules.

The most interesting divergence in truck driver and circadian/sleep expert opinions was in scenario # 4. While 100% of circadian/sleep experts preferred the Non-Compliant

option, 67% of drivers preferred the Compliant alternative. The distinct feature of the Non-Compliant option was a very long day of on-duty and driving beginning at 6 AM and not being completed until 11 PM. While the circadian/sleep experts focused on the benefits of a full night of nocturnal sleep, the majority of drivers saw the number of hours on duty and driving as excessive. However this was not true for every driver. One-third indicated they preferred the Non-Compliant option, again showing that individual differences and preferences are important.

Why Did the Circadian/Sleep Experts and Truck Drivers Select the Non-Compliant Options Over the Compliant Options?

In this study we have identified a strong consensus between two diverse interest but highly informed groups, whom it could be reasonably be argued are best placed to judge the safety and efficacy of the HoS regulations. Each group tells us that the current HoS regulations, rather than ensuring recuperative sleep and alert safe driving, are actually preventing drivers from choosing patterns of sleep, napping and driving which are effective and safe and healthy.

There are therefore a few important questions to ask:

- Where is the gap between the well-established science of circadian rhythms, sleep and alertness and the structure of the current HoS regulations?
- How do we fix this problem in the HoS regulations so as to improve driver sleep, alertness, safety and health?

Identification of the Gap

It is commonly accepted that regulations governing duty, driving and rest hours by themselves can never guarantee the amount of sleep that drivers will actually obtain. While recruiting and hiring responsible safety-conscious drivers and providing them with education and training on sleep and fatigue management are important responsibilities of the trucking carrier, ultimately it is the driver's choice how he spends his off-duty or sleeper-berth time.

However it is critical that Hours of Service regulations are designed to provide any responsible and educated driver with the best opportunity to obtain adequate sleep and to not drive on duty-rest schedules which would cause excessive fatigue. It is therefore of

considerable concern that both the circadian/sleep experts and experienced truck drivers in this study were in agreement that sleep and alertness could be improved by violating the current HoS regulations in a wide variety of driving scenarios.

To pinpoint the cause of the problem we need to look at the substantial body of published science on sleep and alertness and find what has been overlooked in the design of the current HoS regulations. While there are many aspects of circadian and sleep physiology which impact sleep and alertness, we will focus our discussion on the major factors which determine work-rest schedule characteristics, and thus would reasonably fall into the domain of HoS regulation.

Table 3 lists the five key factors which can be influenced by HoS regulations which impact a driver's sleep and alertness. Under each are listed the main contributory factors that need to be considered in the design of regulations.

1. TIME OF CIRCADIAN DAY

An individual's level of alertness and sleepiness varies over the course of the 24-hour day in a predictable pattern with the greatest sleepiness in the early hours of the morning before dawn (typically 1AM-6AM), and a second lesser period of sleepiness in mid-afternoon (often referred to the "post-lunch dip" or the "siesta hour") (Moore-Ede, 1993). Numerous studies have shown that highway accidents caused by sleepy drivers have a peak time of risk around 1-6 AM and secondary time of risk approximately from 1-4 PM (Langlois et al 1985, Horne & Reyner 1995).

It is important to recognize that it is not the clock time on the wall that determines these daily biologic cycles of sleepiness and alertness, but rather the time of day according to the person's biological clock (called the "*circadian phase*"). The circadian phase is determined by two factors relevant to HoS regulations:

a) *Habitual duty-rest schedule:* This is determined by prior time-zone, or duty-rest work shift day-night schedule, and the individual's habitual pattern of bed time and arising time on both work days and weekends/rest days over the prior 1-2 weeks.

b) *Genetic chronotype of individual:* Individuals vary considerably in their orientation to day and night on a morningness-eveningness scale (Horne & Ostberg, 1976, Katzenberg et al. 1998). Morning types tend to rise early and they feel and perform best during the morning hours. Evening types tend to rise late in the morning and they feel at their best late in the evening. It has recently been shown that these characteristics are genetic in nature, and independent of age, sex and ethnic heritage.

Table 3. Key factors Influencing the Sleep and Alertness of Truck Drivers

	Factor	Current HOS Compliant Option	Non-Compliant Option
1	**Time of Circadian Day**		
a)	Habitual duty-rest schedule	–	+
b)	Morningness–eveningness chronotype	–	+
2	**Elapsed Time Awake**		
a)	Time since last rest period	+	+
3	**Duration of Last Sleep**		
a)	Length of rest period	+	+
b)	Time of circadian day	–	+
c)	Sleep need	–	+
4	**Quality of Sleep**		
a)	Time of circadian day	–	+
b)	Sleep environment	–	–
c)	Existence of sleep disorders	–	–
5	**Cumulative Sleep Deprivation**		
a)	Length of rest periods over last week	+	+
b)	Time of circadian day of rest periods over last week	–	+

Table 3: Comparison of ability to address (+) or not address (–) key sleep and alertness determinants in Compliant and Non-Compliant scenario options.

HOS Gap Analysis

Despite the fact that a major FHWA study concluded that the time of day was the strongest and most consistent factor influencing truck driver fatigue (Wylie et al, 1996; Mitler et al, 1997), the HoS regulations (pre-2003, 2004 or 2005) do not directly address the circadian time of day issue, or its main determinants the habitual duty-rest schedule or the genetic chronotype of the driver.

Because the actual determinants of circadian time of day risk are the driver's habitual sleep-wake pattern, and his/her genetically-determined chronotype, and not the local clock time, or even domicile clock time, it is not feasible or practical to write strict

prescriptive regulations regarding the circadian time of day. Any attempts to do so would result in overly complex and unenforceable regulations. It is also vital not to impede a responsible, educated and safety-conscious driver from making informed choices on when to sleep, nap and drive. This is the key difference between the Compliant and Non-Compliant duty rest schedule options in the 12 driving scenarios in this study. Drivers in the Non-Compliant options were able to sleep at circadian times of day most conducive for sleep, and drive when they were most likely to be alert. In the Compliant options the split-sleep rules and 14-hour clock forced drivers to sleep and drive at less favorable circadian times of day.

While the current HoS regulations seek to indirectly address circadian time of day by setting a 14-hour clock limit on driving and a 10-hour minimum rest requirement per day this would promote adherence to a consistent 24-(14+10) hour schedule only if a driver maximized his on-duty time at 14 hours, and kept his rest time at no longer than 10 hours, which seem to be undesirable motivations. By pursuing a more desirable goal of shorter on-duty times, or extended off-duty periods a driver would slip off the 24-hour duty-rest schedule. Furthermore this 14+10-hour concept fails to recognize that the driver's off-duty sleep-wake schedule on any extended period off-duty (for example a weekend at home) may be completely out of synch with a 14+10-hour schedule linked to the arbitrary time in a 24-hour day when he next commences a sequence of duty and rest periods.

2. ELAPSED TIME AWAKE

When a person first wakes up from sleep there is a period of grogginess or sleepiness that resolves typically in less than half an hour. This is referred to as "sleep inertia." Once a person has fully recovered from the residual sleep inertia from his last sleep period the drive for sleep builds with time until the next sleep period occurs. Eventually the extended time spent awake results in a strong sleep pressure. This is referred to as the homeostatic drive to sleep.

The relevant influencing factor in the domain of HoS regulation is:

a) *Time since last rest period:* By placing a 11-hour limit on driving time and a 14-hour limit on on-duty time HoS regulations prevent extended times of driving and on-duty after the last rest period.

HOS Gap Analysis

If every duty period began soon after a driver's sleep period this rule would work well. However in reality drivers can be called for duty at any time in the 24-hour day. This may result in a driver who regularly sleeps 8 hours a day being dispatched after being awake for 16 hours (i.e. just before he would have next gone to bed). Alternatively

drivers who have been off duty for 10 hours or more can be dispatched without notice at any time of day (for example in the early hours of the morning) which may result in a truncated sleep period.

The split-sleep rules and the 14-hour running clock rules in the current HoS regulations actively prevent drivers from making wise choices when to stop for a nap or a sleep period, if their time of dispatch has deprived them of a full sleep period before commencing duty. In the Non-Compliant options, preferred by both experienced truck drivers and circadian/sleep experts, improved sleep opportunities and higher alertness while driving were achieved by violating the current HoS regulations.

3. DURATION OF LAST SLEEP

The length of a sleep period has a well-established effect on the ability to sustain alert and vigilant behavior in the subsequent 24-hour period. Consolidated sleep where the individual has the opportunity to experience all sleep stages (Stage 1, Stage 2, Stage 3&4, and REM) as they progress though several consecutive 90-100 minute ultradian cycles, is important for recuperation from sleep deprivation, and the maintenance of good health. Fragmented sleep[3] (defined in sleep science as sleep disrupted by multiple awakenings per hour (Bonnet, 2005)) such as may occur in sleep disorders such as obstructive sleep apnea, and in soldiers in combat, results in loss of the recuperative value of sleep because the loss of the natural cyclical progression through sleep stages decreases the restorative value of sleep.

The following determinants of sleep duration fall into the domain of Hours of Service regulation.

a) *Length of rest period:* Sleep duration is always less than the duration rest period since even in fatigued individuals it takes a few minutes to stop working, attend to personal matters (bathroom, hygiene and food) and then transition from wakefulness to sleep. In addition, it similarly takes some minutes for a person to awaken and attend to personal matters before duty commences. With this in mind the revisions of the Hours of Service regulations since 2003 have increased the minimum total rest per day from 8 hours to 10 hours, and this is universally accepted as prudent, given the range of individual needs for sleep (discussed in c) below).

b) *Time of circadian day:* Because of the strong effect of the circadian system, sleep duration is highly dependent on the circadian time of day (Czeisler et al 1980). For

3 *The term "fragmented sleep" is incorrectly defined and used in the FMCSA justification of the current Hours of Service (Federal Register pp 49994 September 25, 2005) which has led to significant confusion and misinterpretation of the scientific evidence pertaining to the safety of split-sleep.*

example, there are certain times of day when it is difficult to obtain more than four hours sleep, even under ideal conditions, after extended periods of time awake, and with the most highly motivated individuals.

The studies of Akerstedt and colleagues (Akerstedt 1995) are particularly instructive. They studied subjects (aged 29 – 45) who were given an opportunity to sleep under ideal conditions (quiet comfortable bedroom) during rest periods which started at various times of day or night. Sleep length was not restricted and the subjects were instructed to only get out of bed when they had got all the sleep they could obtain. Even under these ideal conditions, the amount of sleep these subjects were able to obtain was highly dependant on the time of day when the rest period began. Because Akerstedt's studies were conducted with subjects in an age range comparable to many truck drivers, they are more applicable than other studies performed in 18-21 year old college students, who have the hormonally-delayed sleep patterns of late adolescents (Carskadon et al, 2004).

When the rest period began at 11PM at the end of a normal day of 16 hours continuously awake, they slept on average for 8 hours, as one would expect given the unlimited sleeping opportunity. However the later the rest period began after 11PM, the shorter was the sleep duration as a result of the strong circadian time of day effect. Thus when the rest period began at 3 AM (after 20 hours continuously awake) they achieved only 6.5 hours of sleep, when rest began at 7 AM (after 24 hours continuously awake) they obtained only 4.5 hours of sleep; when rest began at 11 AM (after 28 hours continuously awake) they got only 4 hours of sleep.

c) *Individual differences in sleep need:* Individuals vary significantly in their required sleep duration for recuperation with some individuals needing as much as 9 hours per day, while others only need 6 hours. While it is prudent to set the minimum total rest period per day to 10 hours to accommodate the full range of sleep needs, the lower sleep needs of the majority of drivers mean that some flexibility is needed when sleep is considered.

HOS Gap Analysis

This well-established relationship between sleep duration and the circadian time of day sleep exposes a fundamental flaw in the original Hours of Service paradigm that has not been addressed by the current HoS regulations. In fact the revised split-sleep rules introduced effective October 1st 2005 have exacerbated the problem. The current HoS requirement for a minimum 8-hour rest period under these new split-sleep rules, requires that a driver at certain times of day, after getting the maximum physiologically possible 4 hours of sleep, must wait for four to six hours getting "unrested", before being able to drive again. Driving during that illegal 4-6-hour waiting period would most

likely be safe, because it is in such close proximity to the time of waking up from sleep. Starting to drive after waiting in some remote location for four hours is correspondingly less safe.

In the Compliant options reported here such as scenarios # 1 and 6, drivers were given a 10-hour rest period beginning at 9 or 10 AM. This is a highly disadvantageous time of day for sleep, but it is fully compliant with HoS regulations, and treated as if it was equally valuable as a nocturnal sleep opportunity between 11 PM and 7 AM. Both truck drivers and circadian/sleep experts preferred the Non-Compliant option even though it provided for only 7 hours rest taken during nocturnal hours.

The relevance of Akerstedt's studies to the design of optimal rest rules and sleep strategies is vital to understand for trucking operations that have drivers beginning their required rest periods at all times of day and night. The short sleep lengths reported by truck drivers cannot be simply dismissed as a result of less than ideal sleep conditions because of traffic noise, engine idling, and other disturbances. Even in ideal quiet bedroom environments sleep is very truncated at certain times of day.

It is also important to be realistic in HoS regulatory policy and in litigation in establishing the reasonable sleep needs of adults. As Horne (2004) points out, the average adult needs 7 to 7.5 hours, not the 8 or more that has been reported, based on laboratory sleep research studies often performed on college age students, many of whom are too young to obtain a commercial driver license (CDL).

When truck drivers were asked in a FHWA driver fatigue study to complete the statement "My ideal amount of sleep is X hours" they answered on average 7.1 hours (Mitler et al 1997). This is in agreement with other data which supports that 7 to 7.5 hours is a reasonable average daily sleep requirement. For example, it should be noted that 7 hour a night sleepers on average have the greatest longevity (Kripke et al 2002). In a study of over a million people, those who slept more than 8 hours had a substantially greater risk of death in the next six years, as did those who slept 6 hours or less (Kripke et al 2002). Similarly a study of diabetes risk (Ayas et al, 2003) shows a U-shaped relationship between sleep length and risk, with people obtaining 7 hours sleep per night in the middle of the lowest risk range for developing diabetes.

4. QUALITY OF SLEEP

The quality of sleep during any sleep period also influences the sleepiness level on the subsequent day. When sleep is disturbed for example by sleep fragmentation (multiple awakenings per hour), this results in increased sleepiness the following day. The key considerations are:

a) Time of circadian day: The time of day that sleep is attempted has a strong influence on the organization and relative predominance of the various sleep stages, and the number of spontaneous awakenings (Akerstedt, 1995). As anybody who has suffered from jet-lag, or sleep problems when trying to sleep at unaccustomed hours can attest the quality of sleep is significantly altered and insomnia is more common.

b) Sleep environment: Environmental factors such as light/darkness, sound, and temperature have significant effects on the ability to obtain good quality sleep (Moore-Ede, 1993). While not covered by Hours of Service regulations, there are regulatory minimum standards for sleeper-berth accommodation on trucks in 49 CFR Part 393.76. One key factor of especial relevance is the relationship between circadian time of day and sleep environment. Individuals are much less adversely affected by light, noise and temperature when sleeping at their habitual circadian time of day.

c) Existence of sleep disorders: The quality and duration of sleep is substantially affected by over 80 defined clinical sleep disorders that range from the common to the obscure (Kryger, Roth, & Dement, 2005). The most common of the sleep disorders gaining recognition as a significant contributing factor to fatigue in transportation include Obstructive Sleep Apnea, Restless Legs Syndrome and Periodic Limb Movement Disorder.

HOS Gap Analysis

While the requirements for sleep environment are covered in the sleeper-berth regulations (49 CFR Part 393.76) and there are regulations pertaining to sleep disorders (49 CFR Part 391.43), there is no recognition of the strong effect of circadian time of day on sleep quality in the current HoS regulations. As discussed above, the only feasible way to address this issue is to allow drivers more flexibility to select sleep and nap times which are most conducive to obtaining good quality sleep, according to the dictates of their own morningness-eveningness chronotype and their habitual sleep-wake pattern. Prescriptive regulations concerning time of day a driver should sleep are neither likely to be feasible or effective.

5. CUMULATIVE SLEEP DEPRIVATION

It is not just the amount of sleep obtained in the prior 24 hours that determines the level of alertness, vigilance and psychomotor performance. The cumulative effect of sleep or sleep deprivation accumulated over the past week is also important (Carskadon & Dement 1981).

The key parameters relevant to Hours of Service regulation are:

a) Length of rest periods over the past week: As discussed in 3 a) above rest period length provides the outer boundary on sleep length, although the length of the sleep period can be significantly shorter than the length of the rest period. If there has been inadequate time to sleep in the rest periods over the prior 7 days then cumulative sleep deprivation develops.

b) Time of circadian day of rest periods over the past week: As discussed in 3 b) and 4 a) above, the time of day that sleep is attempted has a considerable impact on the amount and quality of the sleep obtained. A cumulative pattern of sleeping out of synch with the driver's optimal circadian time for sleep will result in cumulative sleep deprivation even if the total length of the rest periods over the past week has been more than adequate. Thus a total of 70 hours of rest periods might translate into 56 (7 periods x 8 hr) hours of good quality sleep if taken at the desirable circadian phase, but only 28 hours (7 periods x 4 hours) of sleep if taken at an undesirable circadian phase.

HOS Gap Analysis

By regulating total rest period length and providing disincentives (in terms of lost time or productivity) which restrict the times of day that rest periods may be taken, the current HoS regulations do not provide drivers with the flexibility to address one of the key determinants of fatigue. The scenarios developed and provided to circadian/sleep experts and truck drivers were for trips lasting for multiple days. So part of the effects the two groups considered in their choice of option were the effects of cumulative sleep deprivation. For example in scenario # 10 the Compliant option provided for two consecutive days with 10-hour uninterrupted day-time rest periods, whereas the Non-Compliant option provided for two nocturnal 7-hour sleep periods, plus one afternoon nap. Both circadian/sleep experts and truck drivers decided that a repeating pattern of 7 hours at night was clearly better than repeated 10-hour daytime rest periods, in terms of the sleep obtained and the alertness achieved.

Taken together these five key factors (influenced by a total of 11 main contributory factors) are the principal determinants of the sleep and alertness of truck drivers. As Table 3 shows the current HoS regulations address only 3 of the 11 main contributory factors which determine a driver's alertness on the road. By relaxing the 14-hour clock and the split-sleep rules the Non-Compliant scenario options allowed drivers make the wise decisions needed to address 9 of the 11 main contributory factors. The only two contributory factors not addressed – sleep environment and sleep disorders – were outside the domain of duty-rest regulations, and regulated under 49 CFR Parts 393.76 and 391.43 respectively.

It is thus not surprising that the Non-Compliant options which were in clear violation of the current HoS rules, but allowed 9 of the 11 fatigue-contributing factors to be adequate addressed, were selected as the preferred safe choice by 100% of circadian/sleep experts and the majority of truck drivers.

The solution to this dilemma on how to regulate truck driver duty, driving and rest hours is not the introduction of more restrictive Hours of Service regulations. The complexity of the multiple factors that influence a driver's fatigue as summarized in Table 3, and the interaction between these factors, makes prescriptive regulations very difficult to design and enforce. By its nature transportation by goods by truck has to be a 24/7 activity, for the nation's non-stop round-the-clock economy depends on it. Truck driver fatigue is only one factor in accident risk; even more important is the number of other drivers on the road and their fatigue and behavior (FMCSA, 2006, Hanowski et al, 2007). Nocturnal driving, when congestion and traffic levels are less, has the advantage of reducing other risk factors in the causal chain of accidents. In the next section some ways to address this challenge are discussed.

Addressing the HoS Problem: The Need for Controlled Flexibility

The results of this consensus study of circadian/sleep experts and truck drivers indicate that the split-sleep rules and 14-hour clock unfortunately create negative impacts on truck driver sleep and alertness.

Each long haul truck driver operating under current HoS regulations is thus faced with an unacceptable dilemma on a daily basis:

- Should he comply with the strict HoS regulations which define when he should sleep even if they leave him fatigued?
- Or should he do what he believes is safe? — That is, sleep when his body needs it, and therefore risk being ticketed for an HoS violation.

Because many drivers make the wiser, albeit technically illegal second choice, this has fortunately minimized the safety impact on the highways of the August 25, 2005 split-sleep and 14-hour clock rules that became effective on October 1st 2005. But this an unreasonable burden on the millions of commercial motor vehicle drivers on the roads, and needs to be corrected as soon as possible.

While abuses of HoS regulations are important to control, some of the "cheating" on current HoS rules may be ironically highly desirable. It enables drivers to make sensible decisions based on the physiology of their bodies, rather than a set of rules which this study shows is flawed.

Progress has been stymied by the multiple lawsuits filed by interested parties, but in the interests of public safety it is important to address promptly the negative impact of the current split-sleep and 14-hour clock rules. There are several approaches which should be pursued:

1. Encourage applications for exemptions from the current HoS split-sleep and 14-hour clock rules by trucking companies that provide well-designed fatigue management procedures as an alternative solution to control the risk.
2. Revise the regulations for split-sleep back to the September 2003 rule which became effective January 4, 2004 to allow drivers the necessary flexibility to schedule their sleep at optimal times.
3. Mandate driver fatigue education and training on sustaining an alert and healthy lifestyle.
4. Support the introduction of scientifically-validated fatigue risk models. There are now multiple years of data demonstrating that modifying dispatch and scheduling procedures guided by feedback from fatigue risk models has a substantial effect on reducing driver fatigue, accident and injuries.
5. Provide incentives to introduce and expand driver sleep disorder screening and treatment programs. Sleep apnea is readily diagnosable and treatable with significant safety and health cost benefits.
6. Support the development and testing of alertness monitoring technologies. While this is a back-up safety approach, as compared to the primary approaches of driver and dispatcher education, improved duty-rest scheduling and sleep disorder screening, it is a technology that in combination with the primary approaches can have significant benefit once fully developed and validated.

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Appendix A
Circadian/Sleep Expert Respondents

Name	Position	Affiliation
Torbjorn Akerstedt, PhD	Professor (Psychosocial Factors & Health)	National Institute of Psychosocial Factors & Health, Sweden
	Adj. Professor of Behavioral Physiology	Karolinska Institute
	Deputy Director	Institute of Psychosocial Medicine
Gregory Belenky, M.D.	Research Professor & Director	Sleep and Performance Research Center Washington State University
Drew Dawson PhD.	Director, Centre for Sleep Research	University of South Australia
Charmane Eastman PhD.	Professor, Psychology Department	Biological Rhythms Research Laboratory Rush University Medical Center
Simon Folkard Ph.D., D.Sc.	Professor Emeritus	Université Paris Descartes, Faculté de Médecine, Laboratoire d'Anthropolgie Appliquée, Paris, France
Jim Horne PhD., D.Sc.	Director of the Sleep Research Centre	Loughborough University, UK
Merrill Mitler PhD.	Program Director	National Institute of Neurological Disorders and Stroke; National Institutes of Health
Timothy Monk, Ph.D., D.Sc.	Professor of Psychiatry	University of Pittsburgh School of Medicine
	Director, Human Chronobiology Research Program	Western Psychiatric Institute and Clinic
Allan Pack, M.B., Ch.B., Ph.D	Professor of Medicine, Department of Medicine Chief, Division of Sleep Medicine	Department of Medicine, University of Pennsylvania
Fred Turek, Ph.D	Director, Center for Sleep and Circadian Biology; Morrison Professor of Biology	Northwestern University
James Walsh, Ph.D.	Executive Director, Sleep Medicine and Research Center;	St. John's Mercy Medical Center and St. Luke's Hospital.
	Clinical Professor, Department of Psychiatry	St. Louis University School of Medicine

Appendix B
Participating Drivers

Driver #	Years Experience	Vehicle Type	%Sleeper-Berth Usage
1	6--10	Van	70%--100%
2	20+	Other	70%--100%
3	6--10	Other	70%--100%
4	6--10	Van	70%--100%
5	16--20	Van	50%--70%
6	11--15	Other	70%--100%
7	11--15	Van	70%--100%
8	20+	Van	70%--100%
9	11--15	Van	70%--100%
10	20+	Other	30%--50%
11	16--20	Other	70%--100%
12	11--15	Other	30%--50%
13	4--5	Other	70%--100%
14	20+	Tanker	10%--30%
15	11--15	Van	30%--50%
16	11--15	Van	50%--70%
17	11--15	Van	30%--50%
18	11--15	Van	70%--100%
19	20+	Van	70%--100%
20	11--15	Van	70%--100%
21	20+	Van	50%--70%
22	6--10	Flatbed	50%--70%
23	4--5	Van	30%--50%
24	11--15	Other	50%--70%
25	11--15	Van	50%--70%
26	6--10	Van	50%--70%
27	20+	Other	50%--70%
28	6--10	Other	70%--100%
29	6--10	Other	70%--100%
30	16--20	Flatbed	50%--70%
31	16--20	Van	50%--70%
32	6--10	Van	50%--70%
33	6--10	Flatbed	70%--100%
34	16--20	Van	70%--100%
35	20+	Van	50%--70%
36	11--16	Van	70%--100%
37	11--16	Other	50%--70%
38	20+	Van	50%--70%
39	20+	Van	30%--50%

Driver #	Years Experience	Vehicle Type	%Sleeper-Berth Usage
40	16--20	Van	30%--50%
41	16--20	Tanker	10%--30%
42	16--20	Van	50%--70%
43	20+	Van	50%--70%
44	16--20	Van	30%--50%
45	20+	Van	70%--100%
46	20+	Van	70%--100%
47	20+	Van	70%--100%
48	20+	Van	50%--70%
49	16--20	Van	70%--100%
50	6--10	Van	50%--70%
51	11--15	Van	50%--70%
52	16--20	Van	70%--100%
53	20+	Van	50%--70%
54	20+	Van	70%--100%
55	11--15	Flatbed	50%--70%
56	20+	Flatbed	70%--100%
57	6--10	Van	50%--70%
58	20+	Flatbed	70%--100%
59	16--20	Van	30%--50%
60	16--20	Van	70%--100%
61	11--15	Refrigerated	30%--50%
62	20+	Refrigerated	50%--70%
63	11--15	Refrigerated	50%--70%
64	20+	Refrigerated	50%--70%
65	20+	Refrigerated	30%--50%
66	6--10	Refrigerated	30%--50%
67	6--10	Refrigerated	30%--50%

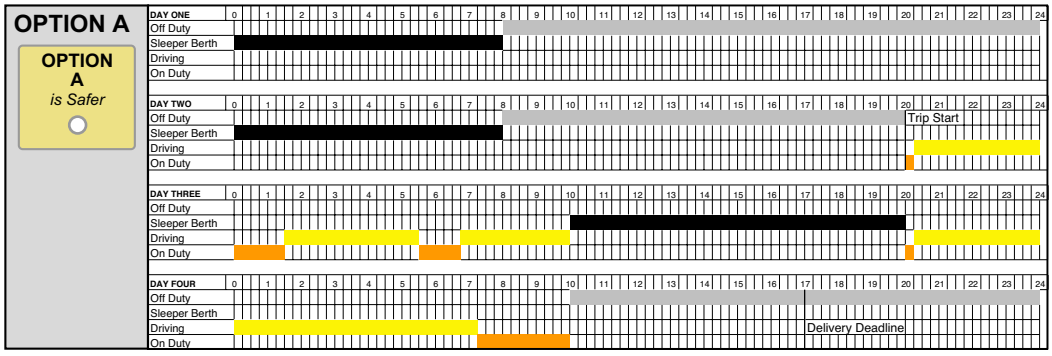
Appendix C
Hours of Service Scenario Options

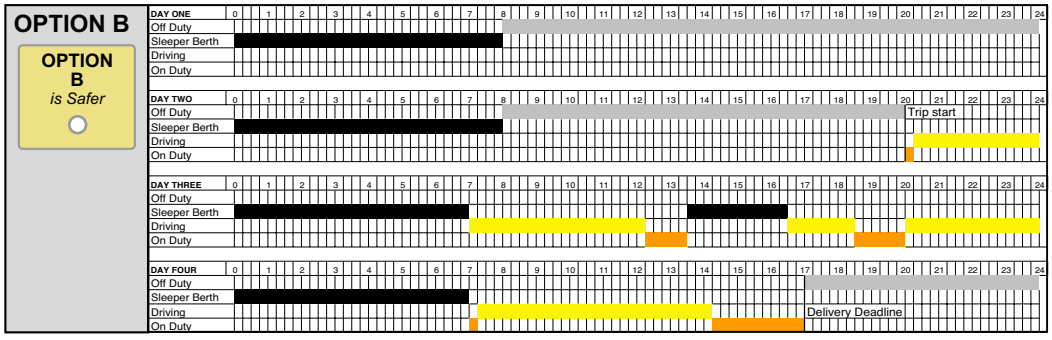
Hours of Service Scenario Options Presented to Circadian/Sleep Experts and to Truck Drivers

In this Appendix we provide screen shots of each of the Hours of Service scenario options that were presented to the Circadian/Sleep Experts and the Truck Drivers participating in the project.

Each respondent was required to choose which of the two on-duty-off-duty-sleeper-berth-driving options (A or B) which was most likely to enable good quality sleep and alertness and safety when driving. Each of the pair of options for a specific scenario had the same trip start time, delivery deadline time and the same number of driving hours to complete the trip. They also adhered to the weekly 60/70-hour driving rules in 7/8 days.

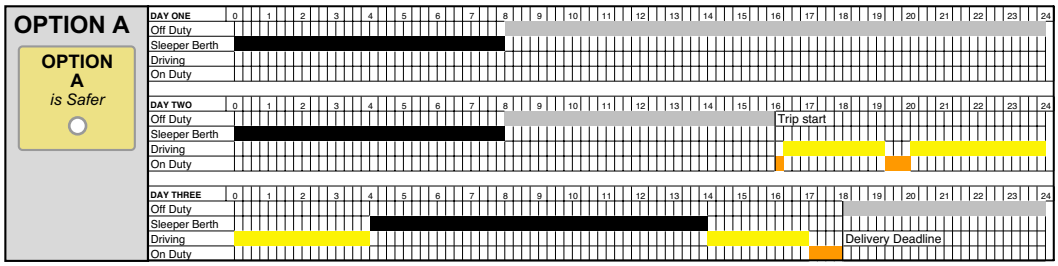
Scenario 1

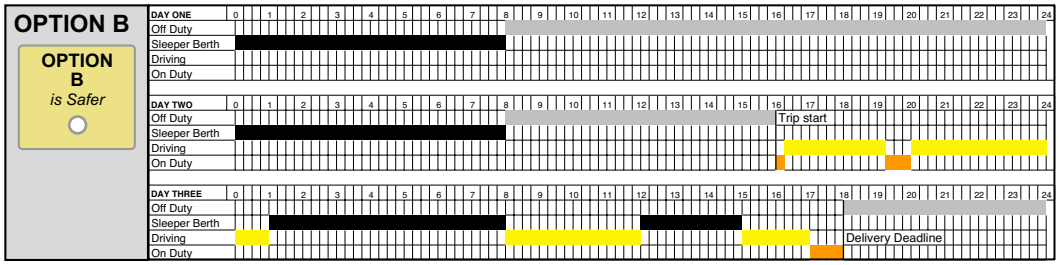




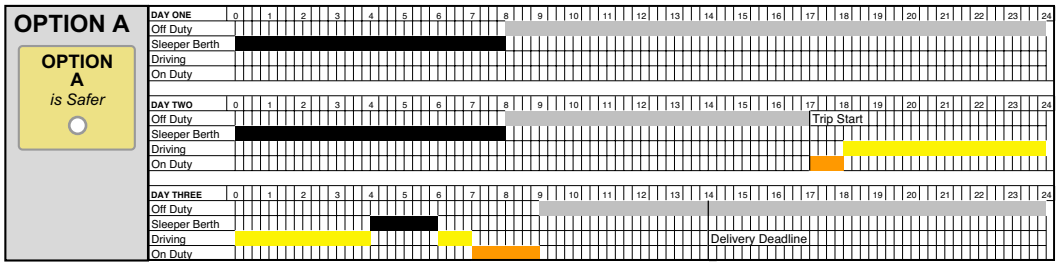
Appendix C
Hours of Service Scenario Options

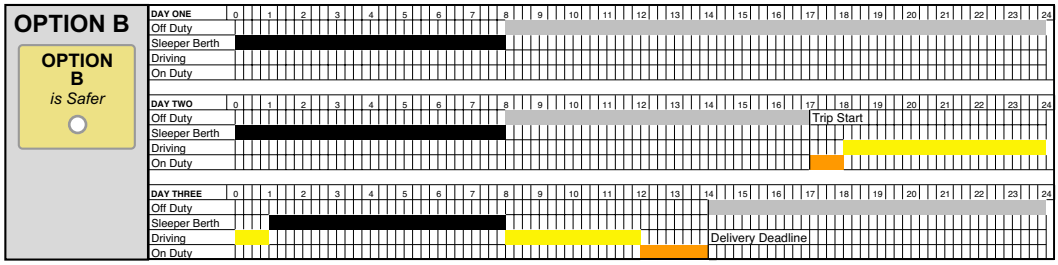
Scenario 2



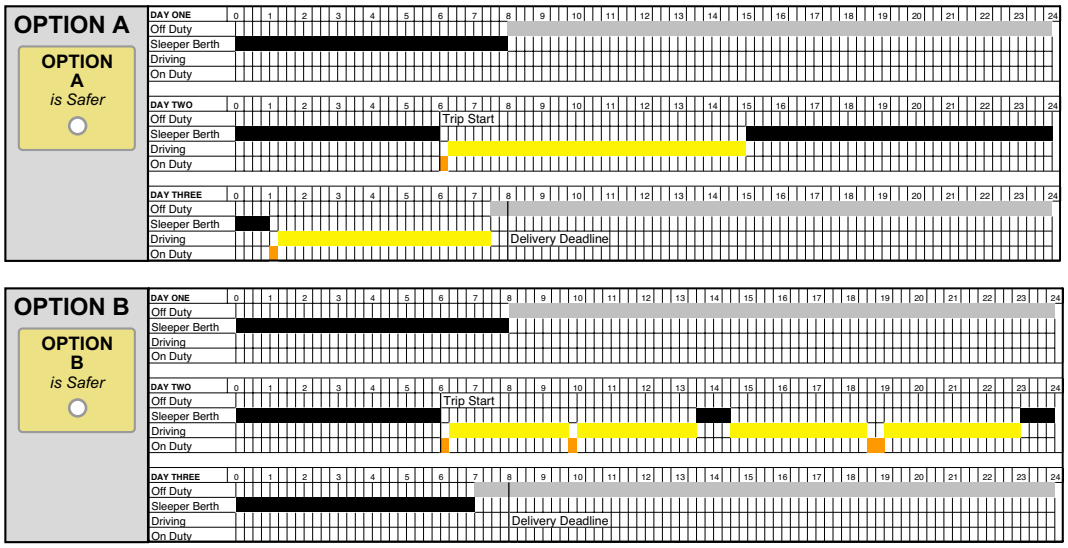


Scenario 3

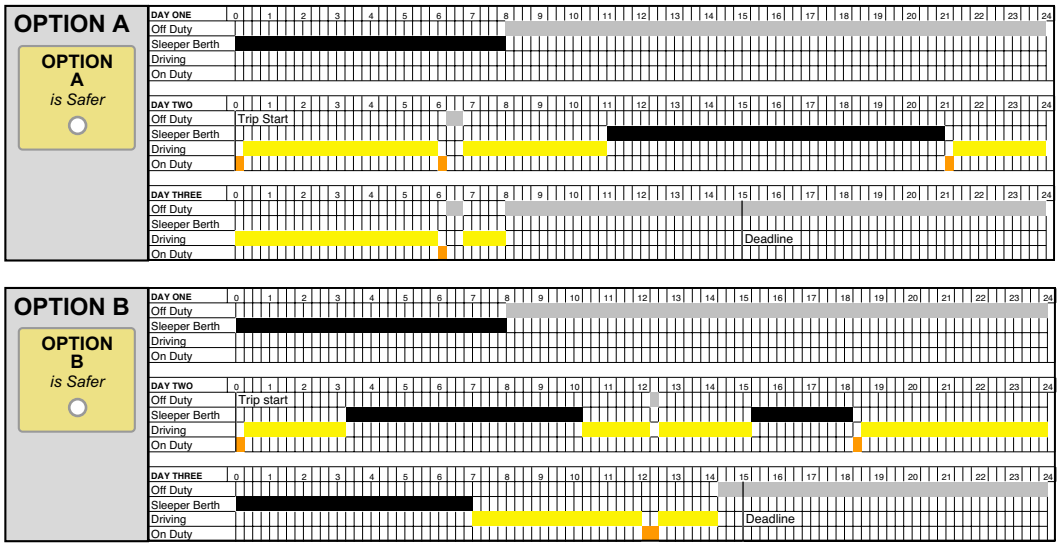




Scenario 4



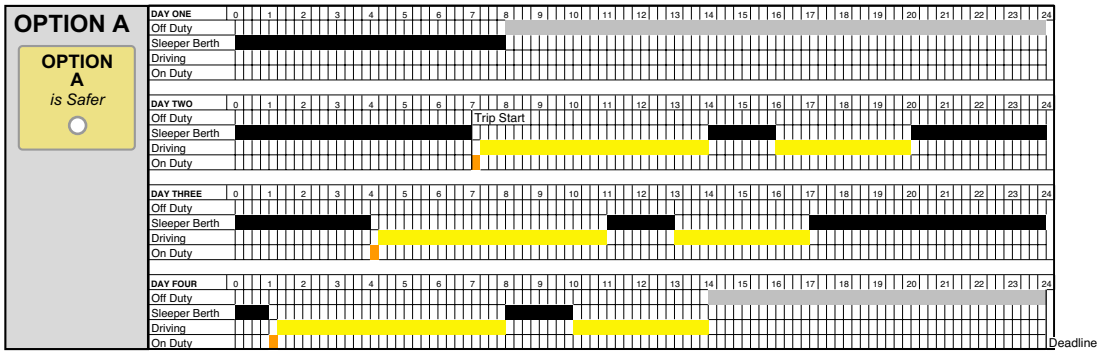
Scenario 5



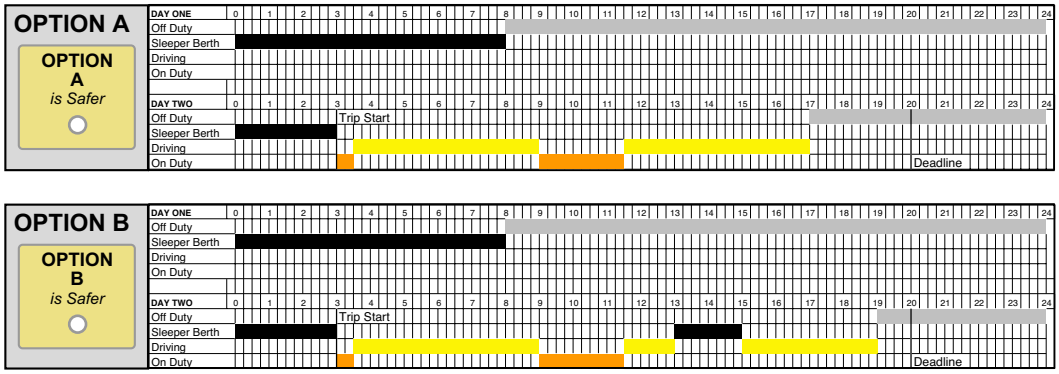
Appendix C
Hours of Service Scenario Options

Scenario 6

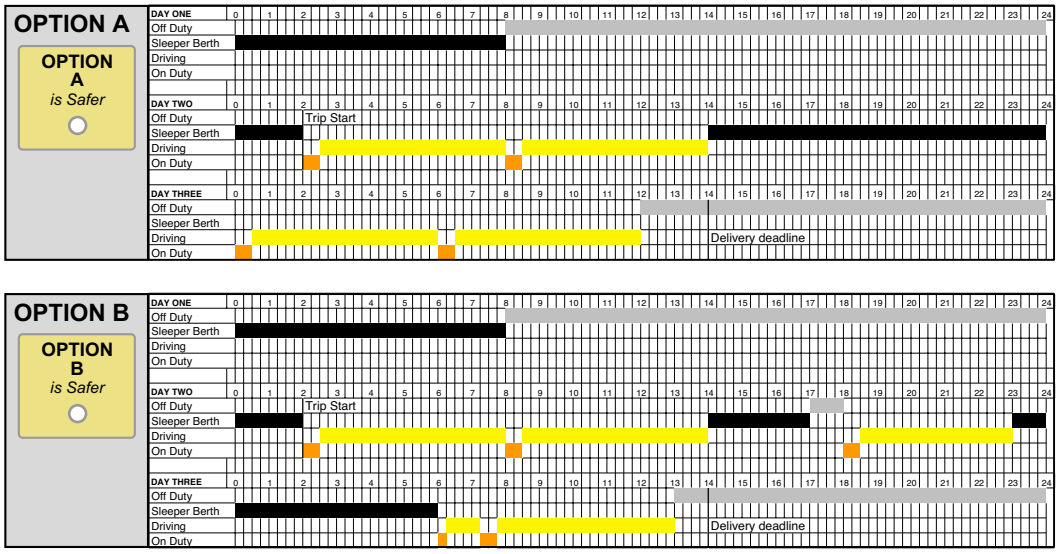
Scenario 7



Scenario 8

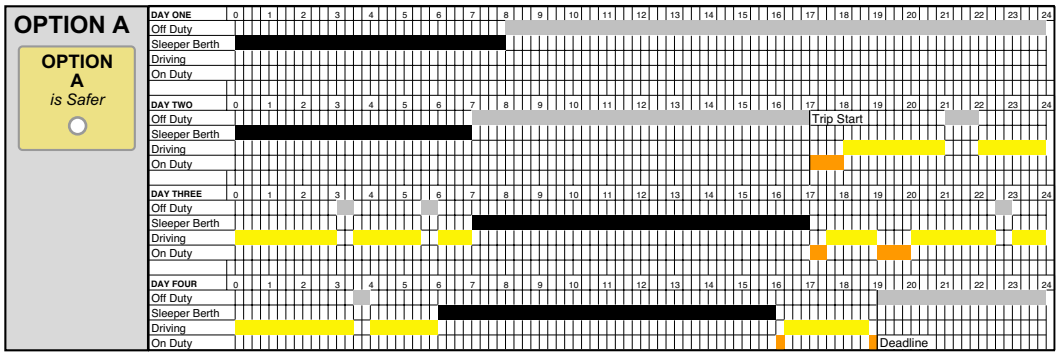


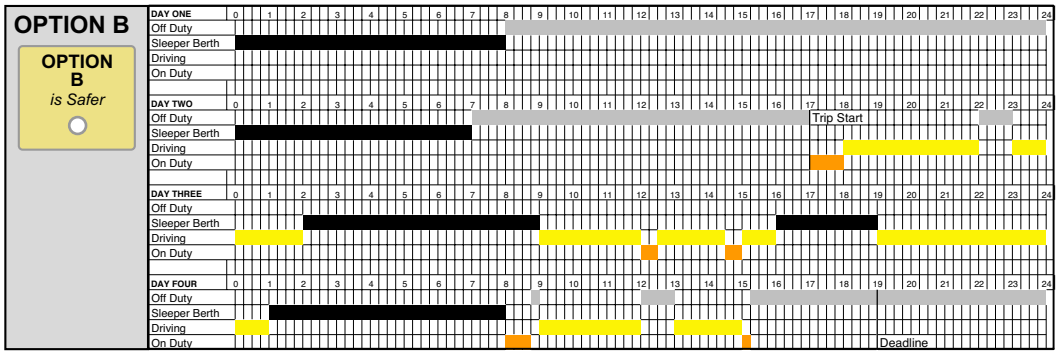
Scenario 9



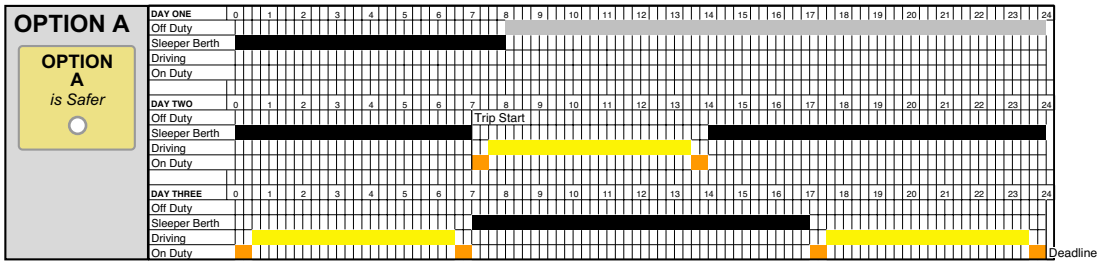
Appendix C
Hours of Service Scenario Options

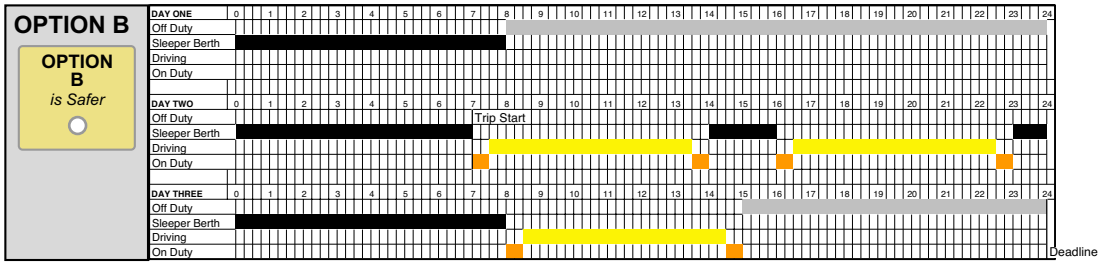
Scenario 10



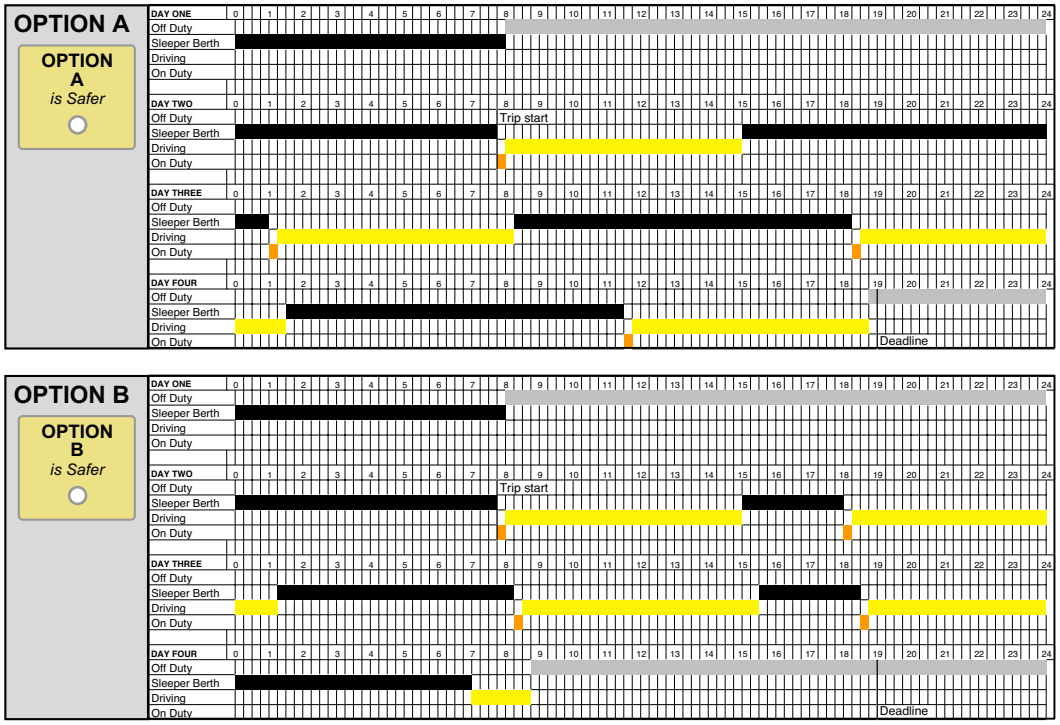


Scenario 11





Scenario 12


OPTION A
OPTION A is Safer
DAY ONE
DAY TWO
DAY THREE
DAY FOUR
Off Duty
Sleeper Berth
Driving
On Duty
Trip start
Deadline
OPTION B
OPTION B is Safer
DAY ONE
DAY TWO
DAY THREE
DAY FOUR
Off Duty
Sleeper Berth
Driving
On Duty
Trip start
Deadline

Appendix D
Example of Driver Comment on HOS Rule

Many responses from drivers have been published in comments to the Hours of Service NPRM, and in letters to Transport Topics, and in many other trucking publications. As one example C.R. England – Comments,(2006), Andrew G. Hardy, a driver, rather forcefully reports:

> *"I only recently become an OTR truck driver. I was flabbergasted to discover that the HOS rules actually prevented me from sleeping when I needed to. It is common knowledge among sleep experts that regularity is vital to getting good sleep. You need to sleep when your body is ready to sleep! It is frequent occurance (sic) for truck drivers that you get a load assignment which requires a late pick-up and an early delivery. The only way to get such a load delivered ontime is to drive all night, take a 10hr break in the middle of the day and then drive all night again. The end result is that you go for 48 hrs with no sleep, because the 10hr break during the middle of the day is worthless. Drivers would be much better served if they had the freedom to break up their sleep period on days they pick-up or deliver so that they could get as much sleep as possible during wee hours of the night when their bodies are ready to sleep and, in fact, trying desperately to do so. Fatigue related accidents happen all the time just within my carriers fleets and they happen in the very early morning hours for just exactly the reason I've described. Do you guys actually care about whether drivers suffer, live or die? Do you care about the safety of the general public? If you do, then you will get new experts to change the HOS rules, so that us truck drivers can start driving well-rested and safe. Your current "experts" seem fixated on this whole "10hrs unbroken" crap. Well, the truth is that, 4hrs of sleep between 2:00 and 6:00 am is vastly more restorative than 10 hrs in the middle of the day. If your "experts" don't understand or appreciate that, then they are a clueless lot of fools and don't agree with the majority of sleep experts out there."*

(C.R. England – Comments, 2006 Document # FMCSA-2004-19608-2465)

About the Author

Martin Moore-Ede, M.D., Ph.D.

For 30 years, Dr. Martin Moore-Ede has been a leading expert on managing the risks of human fatigue in transportation and industrial businesses that operate 24/7. After experiencing the challenges of fatigue as a surgeon-in-training required to work 36-hour shifts, Dr. Moore-Ede was one of the first to define the challenges of living, working and sleeping in a 24-hour a day, 7-day a week world. As a professor at Harvard Medical School (1975 – 1998), he led the team that discovered the biological clock in the human brain that controls the timing of sleep and wake, and pioneered research on how the human body can safely adapt to working around the clock and sustain optimum physical and mental performance.

In 1983 Dr. Moore-Ede founded Circadian Technologies, Inc. (www.circadian.com), a research and consulting firm dedicated to reducing the costs and liabilities of managing a 24/7 workforce. As Chairman and CEO, he has guided the growth of the international network of Circadian corporations and partnerships ("CIRCADIAN") which now advises over half of the Fortune 500 companies on 24/7 work schedules and fatigue risk management. Circadian International, Inc. which conducted this study assists companies in obtaining regulatory waivers and exemptions, and provides expert witness services related to work-rest and Hours of Service regulations and fatigue impairment.

Dr. Moore-Ede graduated with a First Class Honors degree in Physiology from the University of London, and received his medical degrees from Guy's Hospital Medical School, and his Ph.D. in Physiology from Harvard University. He has published 10 books, and 145 scientific papers on human fatigue, errors and accidents and the physiology of sleep deprivation and circadian rhythms. He has served on multiple national and international committees, and has received numerous awards including the Bowditch Lectureship of the American Physiological Society. He is a frequent guest on television (CNN, Today Show, Good Morning America, 20:20, Dateline, Oprah Winfree, Nova, BBC), radio (NPR Fresh Air, Connection), and print media (Wall Street Journal, New York Times, Washington Post, Time and Newsweek). He has testified before Congressional committees on multiple occasions, and advised government agencies on hours of service and working time regulations in the US, Canada and the U.K.

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