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By
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REGULATORY ASSESSMENT
FOR THE HOURS-OF-SERVICE (HOS) RULE

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ACRONYMS

CFR	Code of Federal Regulations
CFS	Commodity Flow Survey
CMV	Commercial motor vehicle
D.C.	District of Columbia
DOT	Department of Transportation
FARS	Fatality Analysis Reporting System
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FR	Federal Register
FTEs	Full-time equivalent employees
GDP	Gross domestic product
HOS	Hours of Service
IFR	Interim Final Rule
LCM	Logistics Cost Model
LH	Long-haul
LTCCS	Large Truck Crash Causation Study
LTL	Less-than-truckload
NAICS	North American Industry Classification System
NHS	National Highway System
NPRM	Notice of Proposed Rulemaking
OOS	Out-of-service
OTR	Over-the-road
PATT	Parents Against Tired Truckers
RODS	Records of duty status
RFA	Regulatory Flexibility Act
RIA	Regulatory Impact Analysis
SBA	Small Business Administration
SCE	Safety-critical events
TIFA	Trucks Involved in Fatal Accidents
TL	Truckload
TOT	Time-on-task
UCR	Unified Carrier Registration
U.S.	United States
VMT	Vehicle miles traveled
VSL	Value of a Statistical Life
VSLY	Value of a Statistical Life Year
VTTI	Virginia Tech Transportation Institute

EXECUTIVE SUMMARY

This Regulatory Impact Analysis (RIA) provides an assessment of the costs and benefits of final rule changes in Department of Transportation (DOT) Federal Motor Carrier Safety Administration (FMCSA) Hours of Service (HOS) regulations. The HOS regulations address the number of hours that a commercial motor vehicle (CMV) driver may drive, and the number of hours a CMV driver may be on duty before rest is required, as well as the minimum amount of time that must be reserved for rest and the total number of hours a driver may be on duty in a "work-week."

This analysis considers and assesses the consequences of four potential regulatory options. Option 1 is to retain the current rule. Option 1 is the no-action alternative, which would retain the provisions of the current HOS rule. All costs are relative to Option 1. Options 2 through 4 require at least one break during the duty day (none is currently required), and limit the use of the 34-hour restart provision to once every 168 hours with at least 2 nights off duty. Options 2 through 4 differ only in driving time allowed between 10-hour breaks. Option 2 limits allowable daily driving to 10 hours, the driving limit that existed prior to the 2003 rule. Option 3 retains the 11 hours of driving allowed under the current rule. Option 4 allows only 9 hours of driving, or 1 hour less than Option 2. This RIA compares the costs and benefits (in 2008 dollars) of Options 2 through 4 relative to the current rule (i.e., Option 1) and assumes that there is full compliance with each of the options.

After profiling the affected industry, this RIA contains chapters describing the methodology for estimating the costs and benefits of HOS rule Options 2 through 4 relative to Option 1. To estimate the costs of operational changes, the basic approach is to follow the chain of consequences from changes in HOS provisions to the way they would impinge on existing work patterns in terms of work and (where relevant) driving hours per week, taking overlapping impacts of the rule provisions into account. Estimated changes in productivity are translated into changes in dollar costs using functions developed for the regulatory analyses of previous HOS rules. Summing the different cost components resulted in a total annualized cost of $1.00 billion for Option 2, $470 million for Option 3, and $2.29 billion for Option 4 (shown in Exhibit ES-1, and broken down by major provision assuming the provisions were added in the same order as shown in the table). Though these costs are estimated using impacts on industry productivity, they would most likely be passed along as increases in freight transportation rates, and then ultimately to consumers in increased prices for the goods that are transported by truck.

Safety benefits are estimated as the monetized reductions in crashes that can be anticipated to follow from reductions in fatigue. The basic approach was to count the changes in hours worked and driven as a result of the regulatory options. Each hour of driving that is prevented results in a reduction in expected fatigue-related crashes. The changes in crash risks were monetized using a comprehensive and detailed measure of the average damages from large truck crashes. This measure takes into account the losses of life (based on DOT's accepted value of a statistical life (VSL), recently set at $6 million), medical costs for injuries of various levels of severity, pain and suffering, lost time due to the congestion effects of crashes, and property damage caused by the crashes themselves. The monetary value of each of the effects thought to affect the safety of drivers was estimated under three different assumptions of the baseline level of fatigue involvements in crashes: 7 percent, 13 percent, and 18 percent. The total benefits resulting from improvements in the safety of long-haul (LH) drivers for Options 2 through 4 are shown below in Exhibits ES-2 through ES-4.

Exhibit ES-1. Total Annualized Costs for Options 2, 3, and 4 (Millions 2008$)

Cost Category	Total – Option 2	Total – Option 3	Total – Option 4
30-minute Break Provision	$90	$90	(combined with driving hour reduction)
Reduction of Daily Driving Hours	$630	(no change in daily driving time)	$2,120
Reduction Due to Restart Provisions	$230	$330	$130
Training and Reprogramming Cost	$40	$40	$40
Total Costs	$1,000	$470	$2,290

Note: Totals do not add due to rounding.

Exhibit ES-2. Safety Benefits (Dollars) for Option 2 (Millions 2008$)

Assumed Percent of Crashes Due to Fatigue[1]	Benefits Due to Reduced Daily Time on Task Effect[a]	Benefits Due to Reduced Weekly Time on Task Effect[b]	Total Benefits Due to Reduced Crashes
7 percent	$110	$210	$320
13 percent	$210	$390	$600
18 percent	$290	$540	$830

a. Acute fatigue from long hours in a day
b. Cumulative fatigue from long hours over many days

Exhibit ES-3. Safety Benefits (Dollars) for Option 3 (Millions 2008$)

Assumed Percent of Crashes Due to Fatigue	Benefits Due to Reduced Daily Time on Task Effect[a]	Benefits Due to Reduced Weekly Time on Task Effect[b]	Total Benefits Due to Reduced Crashes
7 percent	$10	$150	$150
13 percent	$10	$270	$280
18 percent	$10	$380	$390

a. Acute fatigue from long hours in a day
b. Cumulative fatigue from long hours over many days
Note: Totals do not add due to rounding.

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[1] Truck driver fatigue was coded as a factor in 13 percent of all crashes in the Large Truck Crash Causation Study (LTCCS). As a sensitivity analysis, FMCSA also used a lower value of 7 percent involvement in fatigue-related crashes, based on the 8.15 percent value used in the RIA for the 2003 HOS rule. A higher value of 18 percent involvement in fatigue-related crashes also was used as a sensitivity analysis, chosen to be roughly as far above the LTCCS value of 13 percent as the 8.15 percent pre-2003 estimate is below 13 percent.

Exhibit ES-4. Safety Benefits (Dollars) for Option 4 (Millions 2008$)

Assumed Percent of Crashes Due to Fatigue	Benefits Due to Reduced Daily Time on Task Effect[a]	Benefits Due to Reduced Weekly Time on Task Effect[b]	Total Benefits Due to Reduced Crashes
7 percent	$290	$320	$610
13 percent	$550	$590	$1,130
18 percent	$760	$810	$1,570

a. Acute fatigue from long hours in a day

b. Cumulative fatigue from long hours over many days

Note: Totals do not add due to rounding.

For the estimation of health benefits, the analysis focused on reductions in mortality risk due to the decreases in daily driving time and thus possible increases in sleep. For this analysis, we used low, medium, and high baseline levels of sleep to analyze the impacts of changes in hours worked on expected mortality risk to obtain a range of possible health impacts from changes in hours worked. Results of this analysis indicate that the measurable health benefits of reducing the maximum hours of work allowed per week could well be as great as the costs, and other possible health benefits (which have not been included in the quantitative analysis) could add even further to these benefits. The health benefits of Options 2 through 4 were estimated for three different levels of baseline sleep by drivers at 7 and 3 percent discounting of future health benefits (shown in Exhibit ES-5). For the assumption of a high level of baseline sleep for Options 2 and 4, it is interesting to note that the benefits are negative (to a relatively minor extent for Option 2), indicating that it is not beneficial for individuals to get additional sleep if they are already getting adequate sleep.

Exhibit ES-5. Annual Health Benefits for Options 2 through 4 (Millions 2008$)

Assumed Baseline Amount of Nightly Sleep	Total Benefits Due to Increased Sleep					
	7 Percent Discounting			3 Percent Discounting		
	Option 2	Option 3	Option 4	Option 2	Option 3	Option 4
Benefits with Low Sleep	$810	$630	$1,110	$1,090	$850	$1,490
Benefits with Medium Sleep	$380	$350	$370	$510	$470	$500
Benefits with High Sleep	-$50	$70	-$370	-$70	$90	-$500

Net benefits (i.e., benefits minus costs) are likely to be positive, but could range from a negative $730 million per year to more than a positive $630 million per year for Option 2 (a negative $750 million to positive $920 million with 3 percent discounting), from a negative $250 million to more than a positive $550 million for Option 3 (a negative $220 million to a positive $770 million with 3 percent discounting), and from a negative $2.05 billion to more than a positive

$390 million for Option 4 (a negative $2.18 billion to a positive $780 million), as shown in Exhibits ES-6 through ES-8. The wide ranges in estimates of benefits and net benefits are a consequence of the difficulty of measuring fatigue and fatigue reductions, which are complex and often subjective concepts, in an industry with diverse participants and diverse operational patterns. Still, it seems clear that the benefits could easily be substantial, and are on the same scale as the costs. The costs, for their part, are large in absolute terms but minor when compared to the size of the industry: $1.00 billion per year (the total annualized cost for Option 2) is less than two thirds of 1 percent of revenues, $470 million per year (the total annualized cost for Option 3) is less than one third of 1 percent of revenues, and $2.29 billion per year (the total annualized cost for Option 4) is less than 1.5 percent of revenues in the for-hire LH segment of the industry. These total annual costs are an even smaller fraction of revenues of the LH segment as a whole.

Exhibit ES-6. Annualized Net Benefits for Option 2 (Millions 2008$)

Assumed Percent of Crashes Due to Fatigue	Assumed Amount of Nightly Sleep					
	7 Percent Discounting			3 Percent Discounting		
	Low Sleep	Medium Sleep	High Sleep	Low Sleep	Medium Sleep	High Sleep
7 percent	$130	-$300	-$730	$410	-$170	-$750
13 percent	$400	-$20	-$450	$690	$110	-$470
18 percent	$630	$210	-$220	$920	$340	-$240

Exhibit ES-7. Annualized Net Benefits for Option 3 (Millions 2008$)

Assumed Percent of Crashes Due to Fatigue	Assumed Amount of Nightly Sleep					
	7 Percent Discounting			3 Percent Discounting		
	Low Sleep	Medium Sleep	High Sleep	Low Sleep	Medium Sleep	High Sleep
7 percent	$310	$30	-$250	$530	$150	-$220
13 percent	$440	$160	-$120	$660	$280	-$90
18 percent	$550	$270	-$10	$770	$390	$20

Exhibit ES-8. Annualized Net Benefits for Option 4 (Millions 2008$)

Assumed Percent of Crashes Due to Fatigue	Assumed Amount of Nightly Sleep					
	7 Percent Discounting			3 Percent Discounting		
	Low Sleep	Medium Sleep	High Sleep	Low Sleep	Medium Sleep	High Sleep
7 percent	-$570	-$1,310	-$2,050	-$180	-$1,180	-$2,180
13 percent	-$50	-$790	-$1,520	$340	-$660	-$1,650
18 percent	$390	-$350	-$1,090	$780	-$220	-$1,220

Compared to the other two options that were analyzed, Option 2 would have roughly twice the costs of Option 3 (which allows 11 hours of daily driving), and less than half the cost of Option 4 (which allows 9). In keeping with their relative stringencies, Option 3 has lower, and Option 4 has higher, projected benefits than Option 2. Option 3's calculated net benefits appear likely to be somewhat higher than the net benefits of Option 2 under some assumptions about baseline conditions. Option 4's substantially larger costs, on the other hand, did not appear to be justified by its generally higher range of benefits. Based on the estimated net benefits of the options, FMCSA has selected Option 3 as the Final Rule.

This analysis was, of necessity, limited in scope to calculations of what FMCSA judged to be the most important effects of the most important provisions of the rule changes under consideration. We did not separately analyze the circadian effects of the 2-night requirement of the restart provision. It would have been extremely difficult to estimate the magnitude of the additional benefits of taking 2 nights off for night drivers, and would not have changed the conclusion that this provision is cost-effective. The additional costs of this requirement have been included, along with health and safety benefits of the reduction in work hours. The main point of the provision, though, is to address the extra need for rest for drivers on a night schedule. Those circadian-related benefits could not be incorporated at the time this analysis was conducted due to uncertain parameters surrounding the research.

We also estimate the impacts of the HOS rule components individually. To estimate the impacts of the rule provisions, we consider the overlapping effects of the individual rule components to ensure that the impacts of one provision are not also attributed to a second provision. Because this analysis accounts for the individual impact of the rule provisions, the sum of the individual provisions is greater than the combined impact of the rule provisions. Exhibit ES-9 summarizes these differences, rounded to the nearest million to demonstrate the similarity in net benefits for some of these alternatives. Exhibit ES-9 also presents the difference for each option when the provisions are considered separately or as a package.

Option 3, with all three provisions analyzed as a package, is shown to have net benefits of $205 million. That package with the 2 night provision removed (that is, including only the 7 day restart provision and the 30 minute break) appears to have marginally greater net benefits, at $206 million. Not shown in the table, however, are the substantial unmonetized benefits the 2 night provision is expected to have due to the circadian advantages of nighttime sleep. As noted in Section 6.4 of this document, these additional benefits were too complex to be quantified and monetized reliably. They would almost certainly be large enough, though, to ensure that the net benefits of the rule are improved by the inclusion of the 2 night provision. Similarly, the net benefits of a package that excluded the 30 minute break provision appear to be slightly greater than the net benefits of the Option 3 package, at $206 million. Again, the 30 minute break provision is expected to provide very substantial crash reduction benefits that could not be included in the analysis. These benefits, as noted in Section 6.4, are related to the short-term reductions in crashes provided by the break's restorative effects on alertness. If these short-term benefits could be monetized and added to the break's effects on cumulative fatigue, they would almost certainly show it to be a cost-beneficial addition to the rule.

Exhibit ES-9. Component and Interaction Costs, Benefits and Net Benefits For Option 3 (11-Hour Driving Allowed) (Millions 2008$)

Change from Current Rule Baseline	Costs*	Safety Benefits (13 Percent Fatigue)	Health Benefits (Medium Sleep Level, 7 Percent Discounting)	Net Benefits*
7-day restart alone	$342	$227	$318	$204
2-night restart alone	$51	$35	$38	$22
30-minute break alone	$94	$72	$94	$72
Sum of Option 3 provisions, taken separately	$487	$334	$450	$297
Option 3 analyzed as a package	$426	$282	$349	$205
Overlap among Option 3 provisions (difference between sum of separate provisions and package)	$62	$52	$102	$92
Sum of 7 day and 2 night provisions, taken separately	$393	$262	$356	$225
7 day and 2 night provisions, analyzed as a package	$393	$260	$340	$206
Overlap between 7 day and 2 night provisions (difference between sum of separate provisions and package)	$0	$2	$17	$19
Sum of 7 day and 30 minute provisions, taken separately	$436	$299	$412	$276
7 day and 30 minute provisions, analyzed as a package	$374	$253	$328	$206
Overlap between 7 day and 30 minute provisions (difference between sum of separate provisions and package)	$62	$47	$84	$69
Sum of 2 night and 30 minute provisions, taken separately	$145	$107	$132	$94
2 night and 30 minute provisions, analyzed as a package	$145	$95	$127	$76
Overlap between 2 night and 30 minute provisions (difference between sum of separate provisions and package)	$0	$12	$5	$17

*Does not include the $40 million in reprogramming costs.
Note: Totals do not add due to rounding.

1. Background

This Regulatory Impact Analysis (RIA) provides an assessment of the costs and benefits of final rule changes in Department of Transportation (DOT) Federal Motor Carrier Safety Administration (FMCSA, the Agency) Hours of Service (HOS) regulations. The HOS regulations address the number of hours that a commercial motor vehicle (CMV) driver may drive, and the number of hours a CMV driver may be on duty before rest is required, as well as the minimum amount of time that must be reserved for rest and the total number of hours to be on duty and the rest period at the end of a "work-week."

The HOS regulations in effect until 2003 were promulgated pursuant to the Motor Carrier Act of 1935 and codified at 49 Code of Federal Regulations (CFR) Part 395. These regulations were originally promulgated in 1937, and last revised significantly in 1962. They required 8 hours off between tours of duty that could be of indeterminate length, lasting until the driver accumulated 15 hours on duty. They also limited work to 60 hours in a 7-day period or 70 hours in an 8-day period. Concerns that these regulations were outdated and contributed to driver fatigue led to an effort to incorporate new knowledge about fatigue, rest, and their effects on safety.

The 2003 Revised Rule

Revisions to the HOS regulations were proposed in a Notice of Proposed Rulemaking (NPRM) published in the May 2, 2000, *Federal Register* (65 FR 25540). Following reviews of the comments on the NPRM and additional study, FMCSA developed a revised set of HOS regulations. The final rule (the "2003 HOS rule") was promulgated on April 28, 2003 (68 FR 22456), and took effect on January 4, 2004. An RIA comparing the costs, benefits, and impacts of this rule relative to the previous rule and several alternatives was conducted in accordance with the requirements of Executive Order 12866. That RIA, which is available in the HOS rule docket [FMCSA (2002a)],[2] showed that full compliance with the 2003 HOS rule could both save lives and increase productivity compared to full compliance with the rule then in existence. Much of the safety advantage of the 2003 HOS rule was shown to come from the mandate for at least 10 hours off for each tour of duty, and from helping to keep drivers on a regular 24-hour cycle. The contributions to productivity of the new regulations came from a provision allowing drivers to "restart" the accumulation of their 60 or 70 hours on duty within 7 or 8 days once they took 34 hours off at one stretch.

The 2004 Appeals Court Action

After the 2003 HOS rule had been in effect for several months, it was vacated by a Federal appellate court. The United States (U.S.) Court of Appeals for the District of Columbia (D.C.) Circuit held, on July 16, 2004, that FMCSA had not considered effects of the changes in the HOS rule on drivers' health. Public Citizen *et al.* v. Federal Motor Carrier Safety Administration, 374 F.3d 1209 (D.C. Cir. 2004). Additionally, the Court expressed concerns about several areas of the rule, including:

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[2] For a list of the references cited in this RIA, see section 8—References, beginning on page 8-1.

- Permission to drive 11 hours in a tour of duty, rather than 10;
- Allowing more hours on duty in a given week as a result of the restart provisions;
- Allowing drivers to split their off-duty periods into two parts through the use of sleeper berths (that is, bunks within the tractor); and
- Lack of consideration of the use of electronic on-board recorders.

In response to the Court's action, Congress extended the 2003 HOS rule for a year, to give FMCSA a chance to revisit the issues cited by the Court [FMCSA (2003)]. A new HOS rule was published on August 25, 2005, retaining most of the provisions of the 2003 rule but requiring drivers using sleeper berths to spend 8 consecutive hours in the berth and take an additional 2 hours either off duty or in the sleeper berth; this 2-hour period must be counted against the 14-hour on-duty limit (70 FR 49978). The 2005 HOS rule also provided relief to some short-haul operations using lighter trucks [FMCSA (2005a)].

The 2007 Appeals Court Action

Public Citizen and others challenged the August 2005 rule on several grounds. On July 24, 2007, the D.C. Circuit ruled in favor of Public Citizen and vacated the 11-hour driving time and 34-hour restart provisions Owner-Operator Indep. Drivers Ass'n. Inc. v. FMCSA, 494 F.3d 188 (D.C. Cir. 2007). The Court concluded that FMCSA had violated the Administrative Procedure Act's requirements by failing to provide an opportunity for public comment on the methodology of the Agency's operator-fatigue model, which FMCSA had used to assess the costs and benefits of alternative changes to the 2005 HOS rule. In particular, the Court found that the Agency had not adequately disclosed and made available for review the modifications it had made to the 2003 operator-fatigue model to account for time-on-task (TOT) effects in the 2005 analysis. The Court concluded that FMCSA's methodology had not remained constant from 2003 to 2005 because the TOT element in the model was new and constituted the Agency's response to a defect in its previous methodology. The Court concluded that the Agency violated the Administrative Procedure Act because it failed to give interested parties an opportunity to comment on the methodology of the crash risk model that the Agency used to justify an increase in the maximum number of daily and weekly hours that CMV drivers may drive and work. The Court listed several elements of the way FMCSA calculated the impact of TOT that it held could not have been anticipated and that were not disclosed in time for public comment upon them.

The Court also found, turning to Public Citizen's second argument, that FMCSA had failed to provide an adequate explanation for certain critical elements in the model's methodology. In vacating the increase in the daily driving limit from 10 to 11 hours, the Court found arbitrary and capricious what it described as FMCSA's "complete lack of explanation for an important step in the Agency's analysis," the manner in which it had plotted crash risk as a function of TOT per hours of driving. The Court also found that FMCSA had failed to provide an explanation for its method for calculating risk relative to average driving hours in determining its estimate of the increased risk of driving in the 11th hour. In vacating the 34-hour restart provision, the Court found that FMCSA also had provided no explanation for the failure of its operator-fatigue model to account for cumulative fatigue due to the increased weekly driving and working hours permitted by the 34-hour restart provision.

In an order filed on September 28, 2007, the Court granted in part FMCSA's motion for a stay of the mandate. The Court directed that issuance of the mandate be withheld until December 27, 2007.

On December 17, 2007, FMCSA published an Interim Final Rule (IFR) amending the Federal Motor Carrier Safety Regulations, effective December 27, 2007, to allow CMV drivers up to 11 hours of driving time within a 14-hour, non-extendable window from the start of the workday, following 10 consecutive hours off duty (72 FR 71247). The IFR also allowed motor carriers and drivers to restart calculations of the weekly on-duty time limits after the driver has at least 34 consecutive hours off duty. FMCSA explained that the IFR reinstating the 11-hour limit and the 34-hour restart was necessary to prevent disruption to enforcement and compliance with the HOS rule when the Court's stay expired, and would ensure that a familiar and uniform set of national rules governed motor carrier transportation. Public Citizen immediately requested the D.C Circuit to invalidate the IFR. However, on January 23, 2008, the Court issued a *per curiam* order denying Public Citizen's request. On November 19, 2008, FMCSA adopted the provisions of the IFR as a final rule (73 FR 69567).

2008 Petition and Settlement Agreement

On December 18, 2008, Advocates for Highway and Automotive Safety, Public Citizen, the International Brotherhood of Teamsters, and the Truck Safety Coalitions (hereafter referred to as "HOS petitioners") petitioned FMCSA to reconsider the research and crash data justifying the 11-hour driving rule and the 34-hour restart provision. FMCSA denied the petition on January 16, 2009. On March 9, 2009, the HOS petitioners filed a petition for judicial review of the 2008 rule in the D.C. Circuit and, on August 27, 2009, filed their opening brief. However, in October 2009, DOT, FMCSA, and the HOS petitioners reached a settlement agreement. DOT and FMCSA agreed to submit a new HOS NPRM to the Office of Management and Budget by July 26, 2010, and to publish a final rule by July 26, 2011. Subsequently, FMCSA, DOT and the HOS petitioners agreed to publish the final rule on October 28, 2011. The parties filed a joint motion to hold the 2009 lawsuit in abeyance pending publication of the NPRM; the court later accepted that motion.

FMCSA is revising the HOS regulations promulgated in the Agency's current rule. The HOS regulations apply to motor carriers (operators of CMVs) and CMV drivers, and regulate the number of hours that CMV drivers may drive, and the number of hours that CMV drivers may remain on duty, before a period of rest is required. The current regulations are divided into "daily" and "multi-day" provisions, which can be expressed as follows:

- Drivers may drive up to 11 hours following an off-duty period of at least 10 consecutive hours.
- Drivers may not drive after the end of the 14th hour after coming on duty following an off-duty period of at least 10 consecutive hours.
- A driver may obtain the equivalent of 10 consecutive hours off duty if he has a period of at least 8 hours in the sleeper berth and a second period of at least 2 hours either off duty or in the sleeper berth. Compliance is calculated from the end of the first two periods.

- Drivers may not be on duty for more than 60 hours in 7 days (if the carrier operates only 6 days a week) or 70 hours in 8 days (if the carrier operates 7 days a week).
- Any period of 7 or 8 consecutive days can begin following a period of at least 34 consecutive hours off duty.

Several categories of motor carriers and drivers are exempt from parts of the HOS regulations or from the entire HOS regulation under the National Highway System (NHS) Designation Act of 1995 (referred to as the NHS Act).

1.1. PURPOSE AND NEED FOR REGULATORY ACTION

The purpose of the HOS limits is to reduce the likelihood of driver fatigue and fatigue-related crashes. Although the rules that existed prior to 2003 allowed less daily driving than the 2003, 2005, and current rules (10 hours versus 11 hours), the driving could occur 15 hours or more after the driver started working, without any intervening rest, and followed a shorter minimum rest period (8 hours versus 10 hours). The change to a 14-hour consecutive duty period and a 10-hour, rather than an 8-hour, rest period was intended to limit the period in which a driver could operate a CMV and move the driver toward working a schedule that was consistent with the 24-hour circadian clock that humans function on normally. The current rule does not limit the number of hours a driver can perform work other than driving, but if a driver works after 14 hours, he or she must take at least 10 hours off after finishing work before driving a CMV again. The change to a 10-hour off-duty requirement also recognized that drivers need to do other things in their off-duty time besides sleeping; the 10-hour break gives them an opportunity to obtain the 7–8 hours of sleep most people need to be rested and to carry out other necessary day-to-day activities. The 34-hour restart provision was intended to provide drivers with an opportunity to obtain two 8-hour rest periods, which research indicates can overcome cumulative sleep deprivation. Similarly, the sleeper berth provisions in the 2005 and current rules eliminated the practice of splitting time in the sleeper berth into increments that were too short to provide a reasonable period of sleep.

One disadvantage of the restart provision is that it allows drivers to accumulate a substantially larger total number of on-duty and driving time in a 7-day period than the pre-2003 HOS rule allowed. The restart provision, combined with allowing 14 hours on duty per day and 11 hours of driving, enables drivers to accumulate 84 hours of on-duty time in a 7-day period, as opposed to the 60 hours allowed under the previous rule. Under the old rule, drivers could be on duty a maximum of 60 hours in 7 days or 70 hours in 8 days. The restart provision in the current rule allows them to re-set their weekly on-duty allowance after taking 34 consecutive hours off duty. Thus, if a driver maximized daily on-duty time for 5 days, he would reach his 70-hour limit of on-duty time, with 40 hours of off-duty time, for a total elapsed time of 110 hours. A 7-day week contains a total of 168 hours, so after taking 34 hours off duty to reset weekly on-duty time, the driver could then work another 14 hours before taking a final 10-hour off-duty period to end the week, thereby accumulating 84 hours on duty in 7 days. Although few drivers use the rule to these extremes, the potential for drivers to work these extended hours has been a main objection voiced by critics of the current HOS rule.

In addition, although 34 hours would enable a daytime driver to obtain 2 full nights rest with an intervening off day, the same cannot be said for nighttime drivers. Nighttime drivers generally flip their schedules on weekends – going from sleeping during the day and driving at night to sleeping at night and being awake during the day. As a result of flipping schedules, many nighttime drivers would only get one period of consolidated sleep during a 34-hour restart rather than two periods of consolidated sleep. As a result, 34 hours may be inadequate to allow drivers on night schedules to overcome any sleep debt that may have occurred during the work-week. The Agency is concerned that the increase in total maximum allowable work per week allowed by the rule, and the short restart, may result in adverse impacts on driver health and public safety.

1.2. OPTIONS

This analysis considers and assesses the consequences of four potential regulatory options. Option 1 is to retain the current rule, while Options 2, 3, and 4 are to adopt several revisions to that rule. The options and the rationale behind their provisions are described briefly in this section. Based on the estimated net benefits of Options 2 through 4 relative to the no-action alternative of retaining the current rule (Option 1), FMCSA is adopting Option 3.

1.2.1. Option 1

Option 1 is to retain the current HOS rule. The existing exemptions to the current HOS regulations under the NHS Act would remain in effect.

The current HOS rule is divided into daily and multi-day provisions, which can be defined as follows:

- Following 10 consecutive hours off duty, operators can drive up to 11 hours within a period of 14 consecutive hours from the start of the duty tour.
- Short-haul operators of vehicles less than 26,001 lbs. gross vehicle weight/gross vehicle weight rating, remaining within a 150-mile radius of their base, may keep timecards in lieu of logbooks and may be on duty up to 16 consecutive hours for 2 days during a 7-day work week.
- Operators cannot drive after being on duty up to 60 hours during the last 7 days or 70 hours during the last 8 days.
- If a sleeper berth is used, the equivalent of the normal 10-hour off-duty break is an 8-hour period in the sleeper berth and an additional 2-hour period either in the sleeper berth or off duty; provided that the duty periods preceding and following each of these two periods sum to no more than 14 hours.
- Operators who obtain 34 consecutive hours of off-duty time can begin a new period of 60 hours in 7 days or 70 hours in 8 days (i.e., the 7- or 8-day “clock” is restarted by a 34-hour off-duty period).

1.2.2. Option 2

This Option differs from Option 1 as follows:

- Following 10 consecutive hours off duty, operators are limited to 10 (rather than 11) hours of driving within a period of 14 consecutive hours from the start of the duty tour.

- Operators may not drive if more than 8 hours have elapsed since the driver's last off-duty or sleeper-berth period of at least 30 minutes.
- The 34-hour restart must include at least two periods between 1:00 a.m. and 5:00 a.m. A driver may begin another 34-hour restart no sooner than 168 hours (7 days) after the beginning of the last restart. The driver must designate whether any period of 34 hours off duty is to be considered a restart.

1.2.3. Option 3

Option 3 differs from Option 2 only in the amount of driving allowed within a duty period. Option 3 allows 11 hours of driving, or 1 hour more than Option 2.

1.2.4. Option 4

Option 4 differs from Option 2 only in the amount of driving allowed within a duty period. Option 4 allows only 9 hours of driving, or 1 hour less than Option 2.

1.3. BASELINE FOR THE ANALYSIS

This RIA compares the annualized costs and benefits (in 2008 dollars) of Options 2 through 4 relative to the current rule (i.e., Option 1),[3] and assumes that there is full compliance with each of the options. This approach ensures that the analysis captures the full effects of the options' provisions on costs and benefits. To examine the degree to which this assumption may differ from actual practice, FMCSA examined CMV roadside inspection data from 2004, the first full year the main provision of the current HOS rules were in effect, through 2009, the last complete year of data, to assess changes in carrier compliance with the HOS rules, focusing on those violations severe enough to warrant out-of-service (OOS) orders. Exhibit 1-1 shows the overall HOS OOS violation rates and the most prevalent types of individual violations (the OOS rate will be less than the sum of the individual categories because an inspection can result in multiple OOS violations). From 2004 to 2009, the overall OOS rate declined to about 84 percent of the initial level. OOS rates for the 11-hour driving limit declined to 67 percent, and OOS violations related to missing, incomplete, improper, or fraudulent "records of duty status" (RODS) declined to 84 percent of initial levels. Although there are not enough years of data to determine whether the declines in the HOS OOS violation rates in 2008 and 2009 are permanent, so far, incomplete inspection data for 2010 are showing further declines in the HOS OOS rate compared to that in 2009. These data represent the Agency's best estimate of the current state of HOS compliance; and, although there may be some uncertainty as to whether they are the most robust assessment of baseline non-compliance with the HOS rules, projections of future non-compliance rates would be difficult to construct and would have high degrees of forecast uncertainty.

As can be seen from Exhibit 1-1, noncompliance rates, as measured by roadside inspection data, vary fairly significantly from year to year. It is also likely that roadside inspections identify noncompliance less than perfectly. As a result, it is difficult to project compliance rates for any

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[3] Please refer to Appendix C of the RIA for a presentation of the present value costs and benefits of Options 2 through 4 for a 10-year analysis period, using 3 and 7 percent discount rates.

HOS rule based on data available to the Agency. In any case, assuming less than full compliance with the new rule would cut the estimates of both costs and benefits proportionally, so while assuming some rate of non-compliance would affect total costs and total benefits, it would not affect whether any particular scenario had a positive or negative net benefit. In addition, the rank order of the various scenarios from highest to lowest net benefit would not change as a result of incorporating some level of noncompliance into the analysis. We therefore present the full compliance case to capture the full potential costs and benefits of the new rule.

Exhibit 1-1. 2004 – 2009 Hours-of-service Out-of-service Violation Rates

Violation Rate Category	2004	2005	2006	2007	2008	2009	Ratio of 2009 to 2004 Levels
Total HOS OOS Violation Rate	4.6%	4.7%	5.3%	4.9%	4.4%	3.9%	84%
More than 11 Hours Driving	1.4%	1.4%	1.4%	1.2%	1.1%	0.9%	67%
More than 14 Hours On Duty	1.3%	1.3%	2.1%	1.9%	1.7%	1.5%	118%
More than 60 Hours/7 Days or 70 Hours/8 Days	0.4%	0.4%	0.4%	0.4%	0.3%	0.3%	62%
Missing, Incomplete, Improper, or Fraudulent RODS	3.9%	4.2%	4.4%	4.1%	3.7%	3.3%	84%

1.4. SUMMARY OF PREVIOUS ANALYSIS

The previous analysis included in the 2008 "Regulatory Impact Analysis for Hours of Service Options" [FMCSA (2008b)] assessed the potential consequences of two regulatory options. The first option was to readopt the 2005 HOS rule, which allowed up to 11 hours of driving, allowed a new 7- or 8-day period to begin after a 34-hour restart break, and allowed some splitting of off-duty periods using sleeper berth periods of at least 8 hours supplemented by a 2-hour break that could be outside the sleeper berth. The second option was more stringent, and allowed up to 10 (rather than 11) hours of driving and eliminated the restart provision. The second option retained the sleeper berth provisions from the first option. Both options retained the provision in the 2005 rule allowing short-haul operators to use timecards instead of logbooks and to be on duty for up to 16 hours twice during a 7-day period.

The cost analysis divided the industry into broad segments and used a model to simulate carrier operations under different conditions and proposed HOS rules. The model calculated changes in miles driven under the different options. The analysis used that output as a measure of the change in productivity under each option.

The analysis measured the safety impacts of HOS options using an operator fatigue model to estimate changes in crash risks. The analysis multiplied the change in fatigue-related crash risk by the value of affected crashes to estimate the total benefit of the rule.

The analysis determined that the more stringent option would cause a substantial productivity loss relative to readopting the 2005 rule. Industry-wide, the analysis estimated that productivity would decrease by 7.3 percent under the more stringent option, yielding an annual negative productivity impact of $2.4 billion (in 2005$). The analysis determined that the more stringent rule would reduce crash risks by 0.63 percent, yielding a savings of about $214 million (in 2005$) per year. The analysis estimated that the more stringent rule would have a net annual cost of $2.2 billion (in 2005$).

1.5. OVERVIEW OF THE ANALYSIS

This RIA estimates the costs and benefits of changes to the HOS rule (Options 2 through 4) by estimating the incremental costs and benefits of these options compared to the baseline of the current HOS rule (Option 1). Costs of the regulatory options arise due to the operational changes that drivers must make to comply with the new HOS rule provisions. This RIA estimates these costs by determining the losses in productivity that result from the regulatory options for categories of drivers working schedules of varying lengths. These changes in productivity are monetized using a factor estimated for the 2008 RIA [FMCSA (2008b)] which places a dollar value on each 1 percent loss in industry productivity.

Benefits of the regulatory options result from changes in driver safety (i.e., reduction in fatigue-related crashes) and improvements in driver health. Safety benefits are estimated by determining the reduction in driver fatigue levels which result from reductions in daily driving time (where relevant) and in weekly work time. These changes are then monetized using the estimated cost of all LH crashes as a basis for valuing the redistribution of 11th hour driving to other drivers and to other driving days for the drivers whose schedules are truncated. Health benefits of the regulatory options are projected by estimating the potential reductions in mortality risk which result from decreasing work hours and thus potentially increasing sleep for drivers working intense schedules. Reductions in mortality risk are monetized through application of the concept of a VSL and the value of a statistical life year (VSLY). In addition, although not monetized, reductions in long working hours should result in improvements in health for drivers, resulting in lower health care costs and quality of life improvements. The drivers working schedules that approach the limits of the current rules would experience some income loss, because their working hours would be reduced, however; but work, and the associated income, would be transferred to other drivers.

1.6. REMAINING SECTIONS OF THE REPORT

Following this introduction and background, Chapter 2 of this report presents a profile of the affected industry. Following the industry profile are chapters which describe the methodology behind the calculation of the costs and benefits of the regulatory options. Chapter 3 describes the methodology for estimating the costs of operational changes. Chapter 4 describes the methodology for estimating the safety benefits of the regulatory options, and Chapter 5 describes the methodology for estimating the health benefits of the regulatory options. Next, Chapter 6 presents the results of the cost-benefit analysis of the regulatory options. Chapter 7 presents the Regulatory Flexibility Analysis for the Final Rule. Lastly, Chapter 8 presents a summary of the changes in the analysis between the NPRM and this Final Rule. Appendix A presents some additional information on the profile of the affected industry. Appendix B presents a literature review that was conducted on the effect of long work hours and poor sleep on poor health outcomes and mortality risk. Appendix C presents the costs, benefits and net benefits of individual components the HOS Rule under different assumptions of the baseline fatigue level. Appendix C also presents an analysis of the safety benefits of the HOS rule under different assumptions of the effectiveness of the rule for preventing fatigue-related crashes. Appendix D presents more details of the calculations of costs, safety benefits, and health benefits. Finally, Appendix E presents the details of the estimation of the time lost due to the 2-night provision for restarts.

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2. Industry Profile

The industry profile is presented in two parts. The first part concerns the size and structure of the trucking industry, including aspects such as revenue, output, and size of firms. The second part describes the industry's operating practices: hours driven per day, duty hours per day and per week and other measures of intensity of effort relative to the amount of work permitted by the current rule.

Our concentration is on over-the-road (OTR), as opposed to local service. In general, local trucking work has far more in common with "ordinary" work than it does with OTR trucking. Short-haul operations generally involve 5-day-a-week jobs, and much of the time on duty is given to tasks other than driving. Typical workdays are roughly 8 to 10 hours and typical weeks are 45 to 55 hours. Many of these drivers receive overtime pay past 8 hours in a day. Most of the work is regular in character; drivers basically go to the same places and do the same things every day. The rule is expected to have little effect on such operations.

We need a clear definition of OTR service. People in the trucking industry and analysts who study the industry use a verity of terms with varying definitions to distinguish between local moves and longer moves. Many carriers, for example, will distinguish between regional and long-haul service, but with varying definitions of "regional." Some might mean service where a driver can be out and back in a day; others might mean moves that a driver can complete in a day but not be able to get home at the end of the day – and perhaps not get home until the weekend. The former being moves that can be done in a single day, the latter, moves that take more than a day. These kinds of operations are definitely not local; they can involve moves anywhere from 100 to 500 miles in length. For clarity in the analysis, we used only two categories: local service and OTR service.

Both because it makes sense and because of the nature of the available data, we will use 100 miles as the point of demarcation between local and OTR service. Much of our information on working and driving hours is drawn from FMCSA's 2007 "Hours of Service Study," referred to as the "2007 FMCSA Field Survey" [FMCSA (2007b)]. Companies and drivers were identified as operating within or beyond a 100-mile radius. The Economic Census [U. S. Census Bureau (2007a)], which we used for data on revenue, defines a long-distance firm as one carrying goods between metropolitan areas; this is roughly compatible with a 100-mile radius for the distinction between local and OTR service. One hundred miles is also compatible with the length-of-haul classes in the 2007 Commodity Flow Survey (CFS) [Bureau of Transportation Statistics (Research and Innovative Technology Administration, DOT) & U.S. Census Bureau (2010)].

Much of our data is also drawn from FMCSA's 2005 "FMCSA Field Survey: Implementation and Use of the April 2003 Hours-of-Service Regulations," referred to as the "2005 FMCSA Field Survey" [FMCSA (2005b)], in which a local operation is one in which a driver returns to his or her home terminal at the end of every tour of duty. Under this definition, a driver could make one-way runs of at least 200 miles and still be recorded as in local service; this could be somewhat misleading. There is, however, good reason to believe that the great preponderance of the drivers identified as OTR in the 2005 FMCSA Field Survey and as beyond 100 miles in the 2007 FMCSA Field Survey are engaged in the same kind of operation. For this reason, and because of the other data sources, we are comfortable with the local/OTR distinction at 100 miles.

2.1 INDUSTRY SIZE AND STRUCTURE

The OTR trucking industry is not homogeneous. Its various sectors are quite different from one another in their operating characteristics and, therefore, in the way in which they are affected by changes in HOS rule provisions. The principal sectors of the OTR industry are shown in Exhibit 2-1.

Exhibit 2-1. Principal Sectors of Over-the-road Trucking Industry

For-hire			**Private**
Truckload	Less-than-truckload	Other: HHG and packages	

The main line of division in OTR service is between private carriage of goods and for-hire carriage. Within for-hire carriage, there is another major division—between truckload (TL) and less-than-truckload (LTL) operation. There are major differences among the operating characteristics of private carriage and the two types of for-hire carriage, and these differences have important implications for the effects of changes in HOS rule provisions. TL carriers comprise the sector most affected by changes in the rule. OTR private carriers would also be affected, and there are some impacts on LTL services.

“Other” comprises two sectors: household goods (HHG) and small packages. Firms in these sectors do not carry freight, as it is commonly understood, and are not in competition with other types of for-hire carriers. These firms, however, do operate trucks in OTR, as well as local, service and must comply with HOS rules. Their modes of operation are different from those of the main for-hire carriers and those of private carriers. Carriage of packages is dominated by two very large firms—United Parcel Service and FedEx, though there are many other firms in this sector.

2.1.1. For-hire vs. Private Carriage

For-hire trucking firms are paid by others to haul goods. Virtually all of their revenue is derived from movement of freight or related services such as logistics management.

Private carriers are firms that manufacture or distribute goods and choose to carry their own goods. Generally, private carriers do this because they are very sensitive to requirements for timely and reliable service, either because of their own methods of supply-chain management or those of their customers. It is also the case for some private carriers that having their own drivers handle delivery to customers is part of their customer-relations effort.

There are major operational differences between private and for-hire carriage; as a consequence, HOS rule changes would have different effects on these sectors. A major factor is the regular and repetitive character of private carriage that sets it apart from a large part of for-hire service. Regularity, or its absence, in drivers’ schedules makes a significant difference in the effects of

HOS rule provisions. In general, regular operations would be less affected by the options under consideration.

2.1.2. TL vs. LTL Service

The two principal forms of for-hire OTR service differ markedly from one another, both in the kind of service provided and in mode of operation. A TL firm moves a full truckload of freight, for a single shipper, directly from origin to destination. The driver goes to a facility of the shipper where the truck is loaded and drives to a destination point where the truck is unloaded. From there, he proceeds to another origin point to pick up another load and continues in the same manner.

An LTL company, by contrast, moves small shipments (typically in the range of 500 to 2,000 pounds) in a series of moves that involve both local and OTR operation. Local-service trucks pick up shipments from a number of shippers and bring them into terminals where they are consolidated into trailer loads for OTR moves to other terminals where the trailer load is broken down into the smaller individual shipments, which local-service trucks deliver to their final destinations. With few exceptions, LTL OTR runs are overnight.

The dominant pattern for line-haul drivers in LTL operations is driving five nights a week with the weekend (or at least two consecutive days) at home. Some firms will have one group of drivers working Monday through Friday nights and another group working Sunday through Thursday nights. Daytime driving sometimes occurs when, for example, a trailer is to be moved to a terminal that cannot be reached in a single, overnight run.

2.1.3. OTR Revenue, Vehicle Miles Traveled, Tractors, and Drivers

Estimating measures of size and output for the OTR sector presents some difficulty, because there are conflicting trends in different data series. Time series data from American Trucking Associations and the Federal Highway Administration (FHWA) show declining trends for OTR vehicle miles traveled (VMT). The CFS shows increasing ton-miles, and Economic Census data show increasing revenue (after adjustment for price increases).[4] We chose to base our estimates primarily on the revenue data reported by the Economic Census. This choice may be subject to question, but we believe the revenue data, adjusted for price increases, may be the more robust measure of activity and output.

We do not offer estimates of VMT and revenue for the HHG and package sectors. For VMT, this is due to inadequate data. Regarding revenue, we note that these data provide a useful measure of activity levels for the TL and LTL sectors, but revenues from HHG and package service do not provide a meaningful measure of relative levels of OTR operation. That is because OTR movement accounts for a low proportion of total costs in these sectors. Packing and unpacking household goods and local pick-up and delivery of packages are their principal activities in terms of cost.

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[4] Details of data sources and calculations in this section are in Appendix A.

For 2007, data from the Economic Census show revenue of $160.652 billion for OTR for-hire carriage: $122.993 billion for TL, and $37.659 billion for LTL. On the basis of these data and other information, we estimate number of tractors, number of drivers, and VMT as shown in Exhibits 2-2 and 2-3 summarize our estimates for tractors, drivers, revenue, and VMT.

Exhibit 2-2. OTR Tractors and Drivers (Millions)

	Tractors	**Drivers**
Truckload	0.77	0.87
Less-than-truckload	0.11	0.16
HHG	0.04	0.05
Packages	0.04	0.06
Total for-hire	0.96	1.14
Private	0.33	0.41
Total	**1.29**	**1.55**

Exhibit 2-3. OTR VMT and Revenue (Billions)

	VMT	**Revenue**
Truckload	76.9	123.0
Less-than-truckload	15.7	37.7
Total For-hire	**92.6**	**160.7**
Private	19.9	N/A
Total (For-hire plus Private)	**112.5**	**N/A**

NOTE: Table does not include packages and HHG.

2.1.4. Size of Firms and Distribution of Revenue

Regarding number and size of firms, the TL and LTL sectors are very different. While a few thousand LTL firms are listed in most directories, the business is dominated by five national firms and a fairly small number of regional firms. Capital requirements make a high barrier to entry even for regional operations. An LTL operation requires a network of terminals with a fleet of trucks for local pick-up and delivery attached to each terminal. These trucks are in addition to the tractor trailers that make the runs between terminals. A regional firm may need 20 or 30 terminals; national firms may have 300 or more terminals.

The TL sector, by contrast, is a good example of atomistic competition. Barriers to entry are very low; one only needs credit adequate for the purchase of a tractor and trailer. There are more than 70,000 independent firms (not counting leased owner-operators), and a substantial share of TL revenue goes to middle-sized and smaller companies. This is seen in Exhibit 2-4 which shows distribution of revenue by fleet size [FMCSA (2002a)].

We see that firms with 6 to 99 tractors have more than one-third of industry revenue; small and middle-size firms are a robust component of this industry.

Exhibit 2-4. Truckload Firms by Revenue

Number of Tractors	Percent of TL Revenue	Size Classes Combined
1 to 5	8.9%	20.1%
6 to 24	11.2%	
25 to 99	23.3%	48.1%
100 to 499	24.8%	
500 and more	31.9%	31.9%

Exhibit 2-5 shows number of firms distributed across size classes.[5] It also shows that small and middle-size firms are a major element of the industry.

Exhibit 2-5. Number of Truckload Firms by Fleet Size

Tractors	Companies	Percent
1-5	51,884	79.6%
6-10	5,322	8.2%
11-20	3,421	5.2%
21-40	2,186	3.4%
41-75	1,164	1.8%
76-150	649	1.0%
151-500	417	0.6%
>500	128	0.2%
Total	**65,172**	**100.0%**

2.1.5. Local VMT

In the 2003 RIA we estimated, for 2000, 80.0 billion VMT for local carriage, private and for-hire [FMCSA (2002a)]. To update this estimate to 2007, we have used the Gross Domestic Product (GDP) in 2000 and 2007 for a scaling factor. The result is an estimate of 94.5 billion local VMT in 2007.

2.2. OPERATING PATTERNS

To analyze the impact of rule changes, we need to know the prevailing operating patterns in the industry. Of particular interest is the degree of intensity of drivers' work. In other words, we are interested in the degree to which they work close to the limits set by the current rule. To analyze

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[5] Details of data sources and calculations are in Appendix A.

current patterns in work intensity, we assigned drivers to four intensity groups, based on their average weekly hours of work. For this purpose, we used data on weekly work hours from the 2007 FMCSA Field Survey to define intensity groups as shown in Exhibit 2-6.

Exhibit 2-6. Driver Groups by Intensity of Schedule

Driver Group	Average Weekly Work Time	Percent of Workforce	Weighted Average Hours per Week
Moderate	45	66%	29.70
High	60	19%	11.40
Very High	70	10%	7.00
Extreme	80	5%	4.00
			Total: 52.10

Moderate intensity drivers are on duty an average of 45 hours per week. High intensity drivers are on duty an average of 60 hours per week. The third group, very high intensity drivers, works an average of 70 hours per week. The fourth group, extreme-intensity drivers, is on duty an average of 80 hours per week. We used data from the 2007 FMCSA Field Survey to distribute the driver population across these groups as shown above in Exhibit 2-6.

The weighted average is obtained by multiplying the average work time in each class by the fraction of the workforce in that class. The sum, just greater than 52 hours, is the average hours of work per week based on each group's share of the total population. Data analyzed in 2005 from the 2005 FMCSA Field Survey and a large TL carrier suggested a slightly higher industry-wide average work week of 53 hours, which is consistent with 52 hours used in the cost-benefit analysis.[6]

Exhibit 2-7 shows how the weekly work hours for the four intensity groups might break down in terms of days of work per week, hours of work per day, and driving hours per day. Previous analyses (based largely on the 2005 FMCSA Field Survey) showed average days of work per week falling between 5 and 6. Because longer work weeks are naturally associated with more intense schedules, we have assumed that the moderate intensity group typically works 5 days and that the others typically work 6. Those assumptions, combined with the average weekly work hours imply the average work hours per day shown in the exhibit. On the basis of the assumed average work hours per day, and data from the 2005 FMCSA Field Survey showing that driving hours are about 80 percent of work hours, we developed the typical driving hours per workday shown in the exhibit.[7] Finally, the exhibit shows the breakdown of all daily tours of duty by driver group, based on the breakdown of the workforce shown in Exhibit 2-6 and the tours of duty per week shown in Exhibit 2-7. The moderate group of drivers represents a somewhat

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[6] These data are shown in Exhibit 2-6 in the 2008 RIA [FMCSA (2008a)]. Details are in Appendix A.

[7] The data collected in the 2007 FMCSA Field Survey had a slightly different structure than that collected in 2005. As a result, we are unable to calculate driving hours as proportion of total on-duty time from the 2007 data, and hence continue to use the 2005 data as a source for that information.

smaller percentage of all tours of duty than their fraction of the workforce because they are assumed to work fewer tours per week than the other drivers.

Exhibit 2-7. Working and Driving Assumptions by Intensity of Schedule

Driver Group	Average Weekly Work Time	Assumed Typical Workdays per Week	Assumed Average Work per Day	Assumed Typical Driving per Day	Estimated Breakdown of Daily Tours of Duty
Moderate	45	5	9	7	61.8%
High	60	6	10	8	21.3%
Very High	70	6	11.7	9	11.2%
Extreme	80	6	13.3	10	5.6%

We are particularly concerned with the percentage of duty tours in which drivers work close to the current limits in the following ways:

- Working 14 or more hours in a day
- Using the 11th driving hour in a day
- Using the 10th and 11th driving hours in a day

We need to know both the percentage of tours in each group, and the way in which working close to the limit is distributed across the intensity groups. We use 14 working hours for an example of the process. From the 2005 FMCSA Field Survey, we know that 14 or more hours are used in about 9 percent of tours. So the averages for each intensity group, weighted by their contributions to tours of duty, should sum to about 9 percent. We use our judgment and knowledge of the industry to distribute the incidence of use across the four intensity classes. We see this in Exhibit 2-8. (The percentages in the column for assumed use need not sum to 100 percent; they are the percentages of each group's use of the 14th hour.)

Exhibit 2-8. Incidence of Working 14 or More Hours

Work Intensity Group	Percent of Tours of Duty	Assumed use of ≥ 14 Hours	Weighted Average Use
Moderate	61.8%	2%	1.2%
High	21.3%	7%	1.5%
Very High	11.2%	25%	2.8%
Extreme	5.6%	60%	3.4%
			Total: 8.9%

Exhibits 2-9 and 2-10 show the same process applied for use of the 11th driving hour and use of the 10th and 11th hours. As with use of 14 or more work hours, the total weighted averages were obtained from the 2005 FMCSA Field Survey. The 2005 FMCSA Field Survey was used as the basis for these breakdowns because it provided more information on the distribution of daily duty hours, and because a comparison of the 2005 and 2007 surveys showed no significant difference in the use of the 11th hour.

Exhibit 2-9. Incidence of Driving in the 11th Hour

Work Intensity Group	Percent of Tours of Duty	Assumed use of 11th Hour	Weighted Average Use
Moderate	61.8%	10%	6.2%
High	21.3%	25%	5.3%
Very High	11.2%	50%	5.6%
Extreme	5.6%	70%	3.9%
			Total: 21.1%

Note: Total does not add due to rounding.

Exhibit 2-10. Incidence of Driving in the 10th and 11th Hours

Work Intensity Group	Percent of Tours of Duty	Assumed use of 10th and 11th Hours	Weighted Average Use
Moderate	61.8%	25%	15.4%
High	21.3%	50%	10.7%
Very High	11.2%	75%	8.4%
Extreme	5.6%	90%	5.1%
			Total: 39.6%

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3. Methodology for Estimating the Costs of Operational Changes

This chapter presents our methodology for estimating the impacts of the new HOS rule provisions. These impacts result from losses in productivity occurring when drivers change their schedules to comply with the new rule provisions. The productivity loss measured in this analysis is a direct cost to the industry. This loss in productivity is also a societal cost because we assume that industry would pass this cost on to consumers in the form of higher prices for goods. Impacts on consumers of increased freight transportation costs would be small for individual households even for a rule that imposed substantial costs because these costs would be spread among a wide range of goods, purchased by millions of households. Each billion dollars of increased costs, passed on to U.S. consumers in the 117.5 million households estimated for the year 2010 by the U.S. Bureau of the Census, would cost an average household less than $9 per year [U.S. Census Bureau (2010)]. Similarly, a half billion dollar cost would have an impact of only about $4 per household per year.

This chapter first presents an overview of our methodological approach, and then presents a detailed description of the methodology for estimating the impacts of the new rule provisions. We relied, to some extent, on methods used in previous Regulatory Evaluations related to the HOS rules promulgated by FMCSA during the past several years. For a full description of aspects of the methodology used here, please refer to these documents, which can be found in the rulemaking Docket.

3.1. OVERVIEW

This chapter presents the methods used to estimate the costs of the new rule provisions and the alternatives. Before going into detail, however, we present an overview of the approach to provide context for the individual analytical steps. Because the methodology for estimating the costs of operational changes is similar for Options 2 through 4, this chapter first presents details of the methodology for Option 2. In section 3.3 we discuss how the methodology for estimating the costs of operational changes for Options 3 and 4 differs from the methodology for Option 2.

The basic approach for Option 2 is to follow the chain of consequences from changes in HOS provisions to the way they would impinge on existing work patterns in terms of work and driving hours per week, taking overlapping impacts of the rule provisions into account. The resulting predicted changes in work and driving hours are then translated into changes in productivity by comparing them to average hours. The changes in productivity, in turn, are translated into changes in costs measured in dollars using functions developed for the regulatory analyses of previous HOS rules.

Application of the new rule provisions to a widely varying population means we must look separately at the involved intensity groups. While past analyses divided the population into functional groups, ranges, and then into affected and unaffected categories, the need for simplicity and transparency in this accelerated rulemaking led to a division into four intensity categories. Because this rule makes rather marginal changes to the hours of work available for drivers working less than 70 hours per week, we have focused our analysis on the TL sector of the industry. In general, the changes being made in the accompanying Final Rule were designed to impact only those drivers working the most intense schedules. As a result, the changes would primarily impact the 15 percent of drivers who average 70 or more hours on-duty per week. Drivers who average less than 70 hours per week would not be affected by the new restart provision, and would be unlikely to approach the daily driving, on duty, or weekly on duty limits set by the regulatory options. While these drivers may approach 11 hours of driving, or 14 hours on-duty without the imposed 30-minute break, on a particular day, they do so only occasionally. As a result, drivers working more moderate schedules are largely unaffected by the changes. Generally speaking, TL sector drivers work longer hours and more intense schedules than other sectors of the industry, and, as a result, would be the sector most directly impacted by this rule. Data on industry-wide characteristics, combined with data from a limited number of consistent sources on overall intensity, and judgment on how the use of individual rule elements would impact driver schedules gave us a simplified picture of the work and driving characteristics of drivers with varying levels of intensity of work.

The basic approach to calculating the impact of changing the allowable hours of work per day, driving per day, and work per week is to model the existing distribution of these hours, and then estimate what is lost if that distribution is truncated at the upper end, so as to limit the extremes. For example, starting with a large data set on driving hours by LH drivers in individual days of driving from the 2005 FMCSA Field Survey (shown in Exhibit 3-1), we can array the hours of daily driving, and count the number of days that go beyond (in the case of Option 2) 10 hours (to 10.25, 10.5, 10.75, or 11 hours). We can then consider what would happen if no driver can go beyond 10 hours, summing up the number of hours lost for the trips that would have extended beyond 10 hours. For example, a trip that would have gone to 10.5 hours but now must stop at 10 hours loses half an hour. Dividing the total hours lost by the total hours driven gives the estimate of the average change in productivity.

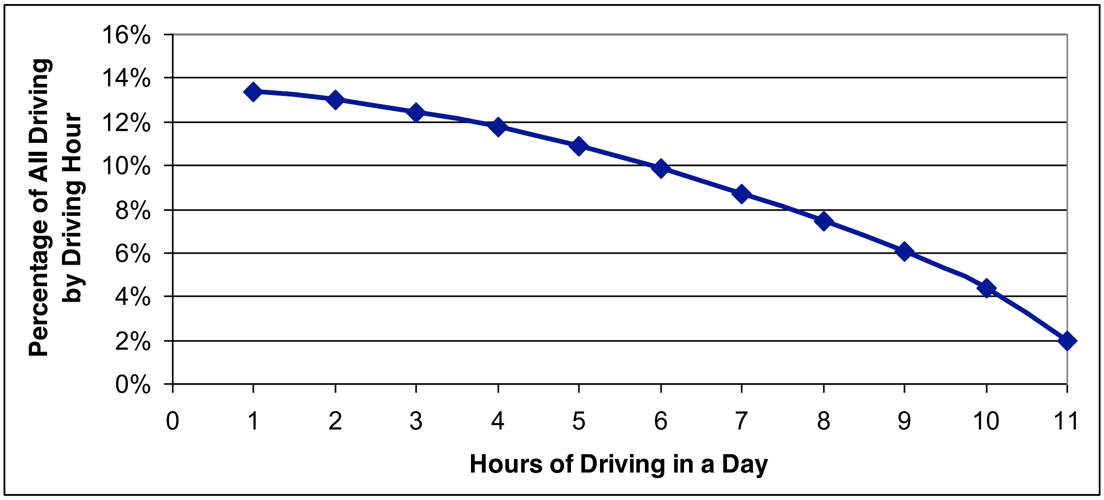

Exhibit 3-1. Percentage of all long-haul driving by hour, based on 2005 FMCSA Field Survey.

We can perform the same calculations for each of the important changes in the HOS rule provisions mandated by the options under consideration. The estimates of the total impacts of the options taken as complete packages, though, have to be more complex than the simple sum of the impacts of the individual provisions, because the provisions interact. Drivers with the highest intensity schedules would be much more likely to lose productivity due to the changes in the restart. Any hours they lose due to the 10-hour driving limit, though, would not be lost again to the change in the restart, and counting both losses would be double-counting. Similarly, hours lost to the 30-minute break provision cannot be re-lost to the 10-hour driving restriction or to the restart restrictions. To capture these effects realistically, we needed to examine drivers in different intensity groups individually.

As an example, consider the provision that requires a 30-minute break during an 8-hour on-duty period. Because all driving time is on-duty time, requiring 30 minutes of off-duty time would reduce, to some extent, the hours a driver would drive in a given day. It is likely that the driver would be forced to reduce driving to some extent, but not by the full 30 minutes as the driver would reduce on-duty, not-driving time to some extent as well. However, because reducing total on-duty time to some extent restricts driving, it is less likely that a driver would hit the 11-hour limit, which would reduce the marginal impact on driving time due to reducing allowable driving from 11 to 10 hours for Option 2. The Venn diagram in Exhibit 3-2 below presents this idea graphically. The area of each circle represents the individual restrictions imposed by the various provisions of the regulatory options. However, these effects interact because restrictions in one area make it less likely that drivers would be able to bump up against limits in another area, thus reducing the marginal impact of the other provisions. These interactive effects are represented by the area where the circles overlap. In order to avoid double or triple counting impacts, we must net out the overlapping sections that have already been accounted for in considering how other provisions affect total weekly work from the total impacts of the rule.

Exhibit 3-2. Venn diagram of rule provision interactions for Option 2.

Data on the breakdown of LH drivers by average hours of work per week was taken from the 2007 FMCSA Field Survey. The distribution of hours of work per day was available only from the 2005 FMCSA Field Survey. That earlier survey was also used as a source for the distribution of hours of driving per day, though a cross-check showed close agreement between the 2005 and 2007 FMCSA Field Surveys in terms of daily driving.

To supplement the industry-wide data on work and driving hours, we made judgments about the way the more extreme hours of daily work and driving are distributed among drivers with higher and lower intensities of weekly work. For example, because it is impossible to build up 80 or more hours of work in a 7-day period without working a maximum daily schedule most of the time, we assumed that on more than half of workdays, drivers working the longest weeks work and drive close to the legal maximum. We assumed the opposite was true for the drivers working the fewest hours per week. As described in Chapter 2, hours of driving and working per day were then assigned to the intermediate weekly work intensities so that the weighted average of long working and driving days aligned closely with the data on the industry-wide prevalence of long days.

Given a set of assumptions about baseline working and driving hours for drivers in different weekly intensity categories, we made judgments about the incremental effects of the changes in HOS provisions on the hours that drivers would be able to drive and work. These judgments, and how they determine the overall changes in productivity, are presented in detail in the sections below.

3.2. DETAILED EXPLANATION OF THE ESTIMATION OF CHANGES IN PRODUCTIVITY

The primary cost of the change in the HOS rule provisions is in the form of lost productivity which occurs when drivers have to change their driving schedules to comply with the new driving and/or working hour limits. This lost productivity would increase the cost of transportation services and ultimately increase the costs consumers pay for goods. To estimate the impact of these operational changes, we used the characterization of the driver population into four groups based on the intensity level of their weekly schedules, as discussed in Chapter 2. This breakdown of the driver population is shown in Exhibit 3-3.

Exhibit 3-3. Driver Groups by Intensity of Schedule

Driver Work Intensity Group	Percent of Workforce	Total Number of Drivers	Average Weekly Work Time	Percent of Work Hours
Moderate	66%	1,056,000	45 hours	57.0%
High	19%	304,000	60 hours	21.9%
Very High	10%	160,000	70 hours	13.4%
Extreme	5%	80,000	80 hours	7.7%

Exhibit 3-3 also shows how the total work effort is assumed to break down across intensity categories. Though the moderate intensity group constitutes 66 percent of all drivers, because they work less than the industry-wide average, their work amounts to a somewhat smaller percentage of all hours of work. The right-hand column of the table shows the breakdown of work implied by the breakdown of drivers and their assumed average weekly hours of work. The values were calculated by multiplying the percentage of all drivers falling into a category by the ratio of that category's average work hours per week to the industry-wide average hours per week. For example, the moderate group constitutes 66 percent of drivers, but their work effort is only 45 hours per week, compared to the industry-wide average of 52.1 hours. Multiplying 66 percent times the ratio of 45 to 52.1 yields 57 percent.

To estimate the impact of the change in operations for Option 2, we first subdivided the operational changes into three distinct effects: the effect of requiring a 30-minute break within an 8-hour on-duty period, the effect of cutting back maximum driving hours from 11 to 10 hours per day, and the effect of the new restart provisions. The 30-minute break provision only impacts those drivers who act under the extremes of the current restrictions and use the 14th hour of daily on-duty time. Drivers not utilizing all 14 hours of on-duty time are likely to be taking breaks within their work shifts, or could adjust their work time slightly to accommodate the 30-minute break provision. We have a reasonably solid estimate of the industry-wide use of the 14th hour from the 2005 FMCSA Field Survey. We used our judgment to allocate the total industry use of the 14th hour across the different categories of drivers. For example, use of the 14th work hour among the total industry is about 9 percent. We distributed the use of the 14th hour among the different categories of drivers so that the weighted average use (use of the 14th hour by each category multiplied by the percent that each category comprises of the total population) of the 14th hour equaled roughly 9 percent. The estimated use of the 14th hour across the different driver categories is shown below in Exhibit 3-4. As can be seen from Exhibit 3-4, the extreme intensity group uses the 14th hour on 60 percent of workdays, on average. However, as presented in Chapter 2, less than 6 percent of workdays are this long, and the drivers working these long hours perform less than 8 percent of the work hours. The partial impact of the 30-minute break provision would be the percentage of time lost to the entire industry due to the cut-back these drivers would have to make in their on-duty time. A simplified example of this calculation would be to take the total time of lost work due to the reduction in on-duty time divided by the total hours the driver would work to find the impact on those drivers' productivity, and then multiplying this number by the percentage of the industry's output that these drivers contribute (in this case 7.7 percent). This calculation would yield the total percentage change in industry productivity that would result from the drivers working the most extreme schedules having to cut back on-duty time per day.

Exhibit 3-4. Assignments of Daily Schedule Intensities across Weekly Intensity Group

Driver Group	Percent of Work Effort	Assumed Use of the 14th Hour of Work	Assumed Use of the 11th Driving Hour	Assumed Use of the 11th and 10th Driving Hour
Moderate	57.0%	2%	10%	25%
High	21.9%	7%	25%	50%
Very High	13.4%	25%	50%	75%
Extreme	7.7%	60%	70%	90%

Further assumptions in how drivers would adjust their use of time given this restriction are needed to identify the total impact on the industry. These assumptions are described more fully below, but involve reasonable judgments about how drivers might re-allocate some of the time they lose on more intense days to less intense days if 30 minutes of off-duty time is required. Even the drivers who work the most intense schedules do not push the daily on-duty time limits every day, which leaves them some room to increase work on these less-intense days. If daily off-duty time is required, they can therefore make up a portion of the time lost on their most intense days by working more intensely on another day that week. While this transfer of work to less intense days would lead to somewhat longer hours on these days, these drivers would still be bound by the 14-hour driving window and the 30-minute break provision. Even with slightly more work on a particular day, their level of fatigue would still be less on these shorter days than it would be on a day when they were working up to the current limits without breaks. We have adjusted for the impact of this transfer of time on safety benefits by modeling crash risk reduction in a way that accounts for the fact that any intra-driver transfer of time would be added to the end of that driver's less intense days. The methodology for these adjustments is described in Section 4.2. We believe our assumptions about this re-allocation of time are reasonable. Similar adjustments are made for the other provisions of the rule.

For the second effect of the operational changes resulting from Option 2, the reduction of driving hours from 11 to 10 per day, we used a similar procedure to estimate the use of the 11th hour by each driver category. From the 2005 FMCSA Field Survey, we know that industry-wide use of the 11th hour is at about 21 percent of daily tours of duty. We used our judgment to allocate use of the 11th hour across the driver categories so that the weighted average use (use of the 11th hour by each category multiplied by the percent that each category comprises of the total daily tours of duty) of the 11th hour equaled roughly 21 percent. The estimated use of the 11th hour across the different driver categories is shown in Exhibit 3-4.

The next step in estimating the impact of operational changes for Option 2 was to determine the incremental impact of each of the two effects on productivity discussed above. First, for the 30-minute break provision, we made judgments for each group of drivers on how they would adjust to the rule. For example, for the high intensity group, we assumed that only half of the 30 minutes (15 minutes) needs to be lost or shifted to another day because the driver is likely to take a break during the day. We assumed that this group would be able to shift half of the 15 minutes to another day, but would lose the other half, for an expected loss of 7.50 minutes. To determine the resulting impact on productivity, we took the assumed number of trips that use the 14th hour and first divided the 30 minutes by two to reflect the fact that most of the days that used the 14th hour would not use the full hour. We then divided this number by two again to reflect the fact that half of this lost 15 minutes could be shifted to another day. This calculation is equivalent to one fourth of the 30 minutes lost (0.50 hours / 4). We then divided this number by the average number of hours worked per day for this group to determine the impact on productivity. The average number of hours worked per day for the high intensity group was assumed to be 10 hours, based on spreading the average weekly work hours of 60 across 6 workdays. These calculations resulted in an incremental impact on productivity of 0.088 percent for the high intensity group (7% × [0.50 hour / 4] / 10 hours). We repeated this calculation for each of the driver categories, using our judgments of how each group of drivers would adjust their schedules to the provisions of Option 2. Drivers with more intense schedules are assumed to lose a greater proportion of time, because they work closer to the daily and weekly limits on a regular basis and therefore have less room to shift any lost time to other days of the week. These productivity impacts were then weighted by each group's share of total industry output. The results of these calculations for all categories of drivers are shown below in Exhibit 3-5.

Exhibit 3-5. Productivity Impacts of the 30-minute Break Provision

Driver Group	Percent of Work Effort	Unweighted Productivity Impact	Weighted Productivity Impact
Moderate	57.0%	~0%	~0%
High	21.9%	0.088%	0.019%
Very High	13.4%	0.536%	0.072%
Extreme	7.7%	2.250%	0.173%

The next step was to weight the estimated productivity impact by multiplying the incremental impact by the percent of all drivers that are in each category of drivers. For the high intensity group, this resulted in a weighted incremental impact on productivity of 0.019 percent (0.088% × 21.9%). In other words, the impact on productivity caused by the 30-minute break provision by the high intensity group comes to 0.019 percent of total industry productivity. These calculations were repeated for the other groups of drivers, and the results are shown in Exhibit 3-5.

Similar calculations were then performed to estimate the incremental impact for Option 2 of cutting driving hours from 11 to 10 per day. First, we made assumptions for each group of drivers as to how they would reallocate their driving time to adjust to the provisions of Option 2. For example, for the high intensity group, we assumed that 35 percent of the driving that would have occurred in the 11th hour can be shifted to some other day. This leaves 0.65 hour on each day that they would have used the 11th hour that is lost. To calculate the impact of this lost 0.65 hour on their productivity, we divided by the average number of hours this group drives per workday. As discussed in Chapter 2, we have assumed this group averages 8 hours of driving per day, based on their average work hours and an assumption that they spend 80 percent of an average day driving. For the high intensity group of drivers, this resulted in a total of 2.03 percent (25% × 0.65 / 8) of lost productivity. We performed similar calculations for the other driver groups, using our judgment of how each group would adjust their schedule to accommodate the provisions of Option 2. The resulting percentages of lost productivity for each driver group are shown below in Exhibit 3-6.

Then, similarly to above, we weighted this productivity impact by multiplying the incremental impact for each driver group by the percent of work hours performed by drivers in that category. For example, for the high intensity group, we multiplied the 2.03 percent of lost productivity by 21.9 percent (the percent of work effort contributed by this group) to obtain a weighted average productivity impact of 0.44 percent. We repeated this calculation for the other driver groups, and the resulting weighted productivity impacts are shown below in Exhibit 3-6.

Exhibit 3-6. Productivity Impacts of Reducing Daily Driving Time for Option 2

Driver Group	Percent of Work Effort	Unweighted Productivity Impact	Weighted Productivity Impact (without Double Counting Adjustment)	Weighted Productivity Impact (with Double Counting Adjustment)
Moderate	57.0%	0.79%	0.45%	0.45%
High	21.9%	2.03%	0.44%	0.43%
Very High	13.4%	4.17%	0.56%	0.52%
Extreme	7.7%	5.95%	0.46%	0.37%

Lastly, to avoid double-counting this impact, we subtracted from this weighted impact the percent of the incremental impact of the 30-minute break provision, much of which comes from driving. An examination of the days that exceeded 13 hours of work in the 2005 FMCSA Field Survey showed that driving hours exceeded 10 on about half of those days. Based on that finding, we assumed that 50 percent of the productivity lost due to the 30-minute break provision comes from driving. We thus subtract 50 percent times the estimated incremental impact of restricting daily work time (0.02%). These calculations resulted in a weighted incremental impact on productivity of just greater than 0.43 percent for the high intensity group (0.44% - [0.02% × 50%]) once the possible double-counting issue was accounted for. These calculations were repeated for the other groups of drivers, and the results are shown in Exhibit 3-6.

The final piece of determining the cost of operational changes for Option 2 was to estimate the impact of the new restart provision. A major impetus behind the restart provision is to allow drivers some flexibility and to reduce some of the negative productivity impacts of the new HOS rule provisions. The restart provision, which can be used once per week, enables drivers to reset their weekly driving limits if they take a break up to 34 hours in length which includes two periods from 1:00 a.m. to 5:00 a.m. This provision has enough flexibility in it to let drivers get in close to 70 hours of work time per week. The restart provision helps reduce maximum work by day drivers by encouraging them to stop before accumulating the full 70 duty hours before a restart. Because this provision only impacts drivers who average more than 70 hours a week of work time, the moderate and high intensity driver groups are unaffected by this provision.

To estimate the impact of the restart provision on the very high and extreme intensity driver groups, it was necessary to first convert the impacts of the restrictions on daily work and driving time to the amount of hours lost per week per driver. To estimate the total hours lost due to the new HOS rule for Option 2, we calculated the hours lost due to the 30-minute break provision and the restriction in daily driving time and summed the two effects to obtain the total hours lost. For the restriction in work time from 30-minute break provision, we multiplied the expected number of hours per day that would be lost by each group by the number of days that group is expected to work in a week. Under Option 2, for example, for the high intensity group, this calculation resulted in a total of 0.05 hour lost per week (7% × [0.50 hour / 4] × 6) due to the 30-minute break provision. We performed similar calculations for the other groups of drivers.

Next, we calculated the hours lost due to the restriction in daily driving time to 10 hours. We calculated this by multiplying the expected number of hours per day that would be lost by each group by the number of days that group is expected to work in a week. For example, for the high intensity group, this calculation resulted in an average of 0.98 hour lost per week (25% × 0.65 × 6) before adjusting for the effects of the 30-minute break provision, and a slightly lower 0.95 hour after the adjustment, due to the restriction in driving hours to 10 hours per day. We performed similar calculations for the other driver groups.

Now that we had an estimate of the hours lost due to the 30-minute break provision and the restrictions on daily driving time, we could estimate the impact of the restart provision. The new restart provision does not affect drivers averaging 60 hours or less per week of work time, so there was no change due to this provision for the moderate and high intensity driver categories. Because these two groups are estimated to account for 85 percent of all drivers, none of the changes in the restart provision will affect more than the remaining 15 percent of drivers. Changes in the restart provisions fall into two categories: the requirement that all restarts include two complete periods between 1:00 a.m. and 5:00 a.m., and the requirement that drivers wait a full week between restarts. The 2-night restart provision will significantly affect only a fraction of the drivers who work more than 60 hours per week because most of them drive during the day and would naturally either comply with the rule or need to make only minimal changes in their schedules. (Drivers who end a series of workdays any time in the late afternoon or evening would be able to start again after 5 o'clock in the morning about a day and a half later, having taken two periods between 1:00 a.m. and 5:00 a.m. Drivers who would otherwise run until 2 or 3 a.m. would need to adjust by only 1 or 2 hours to stop by 1:00 a.m., and so forth). Only drivers who regularly drive the entire night would lose a significant amount of time due to the 2-night restriction. FMCSA believes that some of the largest groups of regular night drivers (including, as discussed in Section 2.1.2, the LTL segment) already take full weekends off, the segment of the population experiencing significant impacts will be small. Data from the 2005 and 2007 FMCSA Field Surveys, on the distribution of start and end times and the lengths of restart breaks, reveal that no more than 32.3 percent of drivers' schedules impinge on the 1:00 a.m. to 5:00 a.m. period, and only about 9 percent would need to be altered by more than 4 hours per restart to comply. Thus, no more than 9 percent of the 15 percent of drivers in the two most intense groups – that is less than 3 percent overall – would be seriously affected.

Using the data on start and end times discussed above, and assumptions about the drivers' most likely response to the need to take 2 full nights off, we calculated that the very high and extreme intensity groups of drivers would lose a weighted average of 0.50 work hour per week as a result of the 2-night restart provision.[8] For the very high intensity drivers, this loss of a weighted average of 0.50 hour would be the only significant impact on their use of the restart. For the extreme intensity group of drivers, the impact of the restart provision was determined by taking the average hours worked per week for this group (80) and subtracting the hours lost due to the restrictions in daily work time (1.80) and the hours lost due to the restriction in daily driving time (2.90) minus 70 hours, which is allowed under the new restart provisions. The loss of 0.50 hour per week due to the 2-night restriction in the restart provision was added to this number, to arrive

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[8] These calculations are presented in detail in Appendix E.

at a total of 5.81 hours ([80 – 1.80 – 2.90 – 70] + 0.50) lost per week due to the new restart provision for the drivers with extremely intense schedules.

Similarly to how lost hours were converted to changes in productivity for the restrictions in daily work time and driving time, we next converted the lost hours due to the restart provisions to lost productivity. For the very high intensity drivers, the loss of 0.50 hour per week due to the restart provisions was divided by the average work hours per week for this group and then multiplied by the percent that this group comprises of total industry effort. This calculation resulted in a total 0.10 percent (0.50 hour / 70 hours × 13.4%) of lost productivity for this group of drivers due to the restart provision. We performed a similar calculation for the drivers with extremely intense schedules.

The next step was to monetize the changes in productivity due to the rule provisions for Option 2. For this step, we used the estimated cost of a 1 percent change in productivity that was calculated in the 2008 HOS RIA. This value was estimated at $335 million (2005$) in the 2008 RIA. This value includes both direct labor costs associated with hiring new drivers and the following non-labor costs:

- **Non-driver Labor** – Costs associated with overhead labor categories that are directly proportional to the number of drivers (e.g., driver managers, load planners, etc.) Thus, hiring more drivers for the 2003 HOS options implied there was a need to hire more overhead labor, leading to non-driver labor costs. We assumed companies spent an additional 4 percent of their total labor cost calculated above on these overhead labor categories.
- **Trucks** – Costs associated with purchasing tractors and trailers for the new drivers.
- **Parking** – Construction and maintenance costs for providing additional parking spaces at terminals.
- **Insurance** – Additional tractor-trailers represent increased capital stock with associated insurance costs (even if firm-level VMT is assumed to be constant).
- **Maintenance** – Additional tractor-trailers also require increased maintenance costs for regular safety inspections and other routine maintenance requirements.
- **Recruitment** – Costs associated with recruiting new drivers.

Inflating this value to 2008 dollars using the GDP inflation index and then adjusting for the slightly lower number of drivers assumed for this analysis (i.e., 1,600,000 as opposed to the 1,632,000 assumed for 2008) resulted in a total of $356 million for each 1 percent loss in productivity. We then multiplied the value of a 1 percent change in productivity by the total percentage changes in productivity estimated for each of the rule provisions that affect productivity. For example, the sum of the productivity impact for the four categories of drivers due to the 30-minute break provision was 0.26 percent (0 for moderate intensity drivers + 0.02% for high intensity drivers + 0.07% for very high intensity drivers + 0.17% for extremely intense drivers). Multiplying this 0.26 percent impact on productivity by the cost of $356 million per each 1 percent loss of productivity resulted in a total cost due to the restriction in daily work time of $94 million. (This cost estimate is shown in Exhibit 6-1, rounded to $90 million.) This calculation was then repeated for the restriction in daily driving time and the restart provision to obtain the total impact due to lost productivity from the new HOS rule provisions.

Next, the impacts of the different rule provisions for Option 2 were summed to estimate the total impact on changes in productivity for each group of drivers. For the high intensity group of drivers, this resulted in a total of 1.01 hours of productive time lost per week. This total resulted from the summation of 0.05 hour lost per week due to the restriction in daily work time from the 30-minute break provision, 0.95 hour lost per week due to the restriction in daily driving time from 11 to 10 hours, and no change in productivity as a result of the new restart provisions. Similar calculations were performed for the other groups of drivers to obtain the total productivity impacts for each category of drivers. We used the calculated changes in weekly work for the estimation of the safety benefits of the new HOS rule provisions, which is discussed in the next chapter.

3.3. ESTIMATION OF COSTS OF OPERATIONAL CHANGES FOR OPTIONS 3 AND 4

In this section, we discuss the changes to the methodology for estimating the operational costs of Option 2 for the estimation of the operational costs for Options 3 and 4. These options differ from Option 2 only in the amount of driving they allow within a duty period. Option 3 allows 11 hours of driving, or 1 hour more than Option 2. Option 4 allows only 9 hours of driving, or 1 hour less than Option 2.

The analyses for Options 3 and 4 are similar in approach to the analysis performed for Option 2, but several assumptions and intermediate calculations differ. Therefore, we discuss the two analyses in terms of how they differ from Option 2.

To estimate the impact of the change in operations, we first subdivided the operational changes into three distinct effects: the effect of the 30-minute break provision, the effect of changes to the maximum driving hours allowed per day, and the effect of the new restart provisions. Option 3 allows the 11th hour of driving per day, so we do not account for those incremental impacts in the changes of operational patterns. Option 4, on the other hand, does not allow the 11th or the 10th hour of driving, so we accounted not only for the productivity impacts incurred by the cut to 10 hours, but also, for those incurred by the cut to 9 hours.

3.3.1 Methodology for Option 3

Option 3 allows for the 11th hour of driving, so the impact on productivity results from the 30-minute break provision and the lost hours due to the new restart restriction. There are also impacts on safety that result from the loss of some fraction of the 11th hour of driving as a result of the 30-minute break provision.

For the 30-minute break provision, we used the same assumptions for the amount of the half hour that must be lost or shifted to another day as we used in Option 2. Next, we multiplied the expected number of hours per day that would be lost by each group by the number of days that the group is expected to work in a week. For example, for high intensity drivers, this calculation resulted in a total of 0.05 hour lost per week ([7% × 0.50 hour / 4] × 6) due to the 30-minute break provision. We performed similar calculations for the other groups of drivers. These impact estimates match those calculated for Option 2.

To calculate the lost 11th hours per week due to the 30-minute break provision, we multiplied the lost hours per week due to the reduction in daily work time by the percent of the productivity lost due to the 30-minute break provision that comes from driving (50 percent). We then multiplied this product by the ratio of the baseline number of hours driven per day to the baseline hours worked per day. We repeated this calculation for all driver groups, and the resulting impacts are shown in Exhibit 3-7.

Exhibit 3-7. Lost 11th Hours Due to the 30-minute Break Provision

Driver Group	Lost 11th Hours
Moderate	0.00
High	0.02
Very High	0.14
Extreme	0.68

An additional impact incurred under Option 3 is the impact of the new restart provision. Similar to Option 2, the new restart provision does not affect drivers averaging 60 hours or less per week of work time, so there was no change due to this provision for the moderate and high intensity driver categories. For the very high intensity group of drivers, the new restart provision was estimated to result in a loss of 0.50 hour per week due to the 2-night restriction in the restart provision (this is the same impact estimated for Option 2). For the extreme intensity group of drivers, the impact of the restart provision was determined by taking the average hours worked per week for this group (80) and subtracting the difference between 70 hours (which is allowed under the new restart provisions) and the hours lost per week due to the restrictions in daily work time (1.80). The loss of 0.50 hour per week due to the 2-night restriction in the restart provision was added to this number to arrive at a total of 8.70 hours ([80 –70 – 1.80] + 0.50) lost per week due to the new restart provision for the drivers with extremely intense schedules.

Next, we converted the lost hours due to the restart provisions to lost productivity. For the very high intensity drivers, the lost productivity under Option 3 matches that under Option 2. For the drivers with extremely intense schedules, however, this calculation resulted in a total of 0.83 percent (8.70 hours / 80 hours × 7.68 %), which differs from the analogous estimate under Option 2.

3.3.2 Methodology for Option 4

Option 4 does not allow for the 10th or 11th hours of driving so the impact on productivity results from the lost 10th and 11th hours of driving, the 30-minute break provision, and the lost hours due to the new restart restriction. We ignored the 30-minute break provision because it would have almost no incremental effect beyond the 9-hour driving limit.

To calculate the incremental impact of the cut to 9 hours of driving, we assumed the following uses of the 10th and 11th hours of driving for the moderate, high, very high, and extreme categories: 25 percent, 50 percent, 75 percent, and 90 percent. In addition, we assumed that 1.50 hours from the 10th and 11th hours are either lost or shifted to another day, because reducing an 11-hour day to 9 hours is a loss of 2 hours, and reducing a 10-hour day to 9 hours is a loss of 1 hour, and 1.50 hours is the average of 2 hours and 1 hour. We assumed that the following fractions of those 1.50 hours can be shifted: 0.35 for moderate intensity driving schedules; 0.25 for high intensity driving schedules; 0.15 for very high intensity driving schedules, and 0.05 for extremely intense driving schedules. These fractions are smaller than for Option 2 because, with the tighter constraint on driving, it is less likely that driving can be increased on other days. We first multiplied the assumed use of the 10th and 11th hours by the hours that must be lost or shifted (1.50) and the fraction of those hours that can be shifted to other days. We then divided the resulting product by the expected number of hours of driving on a typical day to find the fraction of baseline driving that is lost, and multiplied that by the percent of total work effort contributed by the intensity category to find the weighted average impact on productivity. For example, the incremental impact of a cut to 9 hours for the very high intensity category was 1.43 percent (0.75 × 1.50 × [0.85 / 9] × 0.13). We performed similar calculations for each intensity category. The results of these calculations are presented in Exhibit 3-8.

Exhibit 3-8. Incremental Impact of the 9-Hour Driving Time Restriction

Driver Group	Incremental Impact
Moderate	1.99%
High	1.54%
Very High	1.43%
Extreme	0.98%

Similar to Options 2 and 3 above, the new restart provision does not affect drivers averaging 60 hours or less per week of work time, so there was no change due to this provision for the moderate and high intensity driver categories. For the very high intensity group of drivers, the new restart provision was estimated to result in a loss of 0.50 hour per week due to the 2-night restriction in the restart provision (as for the other options). For the extreme intensity group of drivers, we estimated the impact of the restart provision by taking the average hours worked per week (80) and subtracting the difference between the 70 hours allowed under the new restart provisions and the loss due to the restrictions in daily driving time (7.70). The loss of 0.50 hour per week due to the 2-night restriction in the restart provision was added to this number, to arrive at a total of 2.81 hours ([80 – 70 - 7.7] + 0.50) lost per week due to the new restart provision for the drivers with extremely intense schedules.

We next converted the lost hours due to the restart provisions to lost productivity. For the very high intensity drivers, the impact is the same as in Option 2 and Option 3. For the drivers with extremely intense schedules, this calculation resulted in a total of 0.27 percent (2.81 hours / 80 hours × 7.68 %).

4. Methodology for Estimating Safety Benefits

This chapter presents our methodology for estimating the safety benefits of the new HOS rule provisions. These benefits result from reductions in fatigue risk due to the decreases in daily driving time and weekly work time. In this chapter, we first present an overview of our methodological approach, and then present a literature review on fatigue risk and TOT, and, finally, we present a detailed description of the methodology for estimating the safety benefits of the new rule.

4.1. OVERVIEW

As with the previous section, this presentation of the methods used to estimate safety benefits begins with an overview of the approach before going into detail. Safety benefits are the monetized reductions in crashes that can be anticipated to follow from reductions in fatigue. In past regulatory analyses, the effects on fatigue, and fatigue-related crashes, of changing the HOS rule provisions were calculated using fatigue models. These models (the Walter Reed Sleep Performance Model for the 2003 rule [Balkin, *et al.* (2002)], and the closely related SAFTE/FAST Model for later analyses [Eddy & Hursh (2001)][9] took into account the drivers' recent sleeping and waking histories, and calculated fatigue based on circadian effects as well as acute and cumulative sleep deprivation. These models did not incorporate a function that independently accounted for long hours of driving in a single day (i.e., acute TOT), neither did they explicitly account for the effects of cumulative hours of work (as opposed to off-duty time) during several days. These effects were assumed, instead, to be accounted for in the effects of long daily and weekly work hours on the drivers' ability to sleep. For the 2005 and later analyses, a separate TOT function, based on statistical analysis of Trucks Involved in Fatal Accidents (TIFA) data [Matteson, *et al.* (2008)], was added to ensure that available evidence for TOT effects was not ignored; those analyses were still criticized as deficient for excluding consideration of cumulative TOT effects.

For the current analyses, FMCSA is replacing the use of the sleep-related fatigue models with a simpler approach that explicitly incorporates fatigue related to hours of daily driving and hours of weekly work. The function used to model the effects of daily driving hours is the same as that used since 2005, while the function for modeling weekly work hours is taken from FMCSA's analysis of the Large Truck Crash Causation Study (LTCCS) [Toth, *et al.* (2006)]. Because both fatigue functions – for daily driving (TOT) and cumulative fatigue (weekly work hours) – used in the RIA were estimated independently without taking multiple factors into account, it is theoretically possible that each one incorporates some of the effect of the other. This circumstance could, then, lead to a measure of double-counting, if some of the apparent effect of long driving hours is actually due to long work hours in previous weeks, and vice versa. Our analysis of the data shows that, in this case, there is almost no correlation between the variables (because the 11th hours are spread across all categories of drivers). Because there is little correlation (with no statistical significance) between hours driven today and hours driven in the past week, the two functions operate independently of one another, and hence there should not be any concern about double-counting of benefits. Other fatigue effects, including the effects of

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[9] Please visit www.fatiguescience.com for more information on the SAFTE/FAST Model.

insufficient sleep and the circadian effects of working and sleeping at sub-optimal times, are implicitly assumed to be incorporated in the daily driving and weekly work hour functions because those effects were at work on the drivers involved in the crashes recorded in TIFA and LTCCS. To add fatigue effects calculated by a sleep/performance model on top of the empirically based functions would, therefore, run the risk of double counting the benefits of restrictions on work and driving. These functions, and the uncertainty surrounding them, are described further in the following sections.

The basic approach for using the empirically based fatigue risk functions is to count the changes in hours worked and driven as a result of the regulatory options. Each hour of driving that is prevented results in a reduction in expected fatigue-related crashes. These reductions are calculated using the predicted levels of fatigue-related crashes indicated by the fatigue functions. The hours of driving and working that are prevented by the options, though, are assumed to be shifted to other drivers or to other workdays rather than being eliminated altogether. The fatigue crash risks for those other drivers and other days are also taken into account. Taking account of these partially offsetting risks means that that the predicted crash reductions attributable to the options are really the net effect of reducing risks at the extremes of driving and working while increasing risks for other drivers and on other days.

The changes in crash risks are monetized using a comprehensive and detailed measure of the average damages from large truck crashes. This measure takes into account the losses of life (based on DOT's accepted VSL, recently set at $6 million), medical costs for injuries of various levels of severity, pain and suffering, lost time due to the congestion effects of crashes, and property damage caused by the crashes themselves [Zaloshnja & Miller (2007)].[10]

4.2 LITERATURE REVIEW ON FATIGUE AND WORK

Workers experience a number of different types of fatigue while on the job. The three major types of fatigue affecting work performance are industrial, cumulative and circadian [Saccomanno, *et al.* (1995)]. These types of fatigue are described below, focusing on the literature relating to truck drivers.

Industrial fatigue results from working continuously throughout an extended period of time without proper rest, often referred to in the literature as fatigue resulting from TOT. For example, a truck driver who has been driving for 8 hours, without a break, might be subject to industrial fatigue. Some studies have shown performance to decrease as TOT increases [Dinges & Kribbs (1991)]. TOT problems could be exacerbated by sleep loss, even in the early stages of the task. One study concluded that for sleep-deprived individuals, performance is compromised even at early stages of performance of a monotonous task if the situation is undemanding and boring. This study suggested that the effect of sleepiness becomes immediately evident in the form of reduced vigilance [Gillberg & Akerstedt (1998)].[11]

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[10] Average large truck crash costs were obtained from this report. The cost of a crash was updated to 2008 dollars and to reflect a value of a statistical life of $6 million.

[11] "Vigilance" was measured through a 34-minute visual vigilance test.

Cumulative fatigue arises from working for too many days on any protracted, repetitive task without any prolonged break. This fatigue results from a lack of alertness brought on by familiarity and boredom with the task at hand. A truck driver could experience cumulative fatigue, for example, under the current HOS rules, after working for 14 hours, taking 10 hours off and then working another 14 hours (working a total of 28 hours in a 38-hour period).

Circadian fatigue is a function of the circadian rhythm. Fatigue is greatest when approaching or at the nadir of the circadian cycle, where the body is least vigilant. The truck accident rate is much higher during the early morning hours than during any other time of day, supporting the circadian effect hypothesis that accidents are more likely to occur when the human body is least vigilant [Harris (1978)].[12]

Night and rotating shift workers are especially susceptible to being fatigued on the job [Akerstedt (1988); Mitler, *et al.* (1988); Gold, *et al.* (1992)]. Permanently assigned graveyard-shift workers sleep between 5.8 to 6.4 hours per day [Bonnet & Arand (1995)]. Rotating shift workers, such as many truck drivers, sleep even less when they work a night shift (5.25 to 5.5 hours). Shift workers experience disturbances in their circadian rhythm, as measured by changes in hormonal levels [Akerstedt & Levi (1978)]. They are also less alert during nighttime shifts and perform less well on reasoning and non-stimulating tasks than non-shift workers [Akerstedt (1988); Akerstedt, *et al.* (1981)]. Though nightshift work for many workers is regular (i.e., the same schedule is kept over time), truck drivers often have irregular schedules which can amplify the effects of circadian, cumulative, and industrial fatigue and increase the risk of fatigue-related accidents.

4.2.1 Fatigue and Truck-involved Accidents

Fatigue increases throughout the duration of trips, regardless of the driving schedule [Williamson, *et al.* (1996)]; and total driving time has a significant effect on crash risk, though there is variation on the point at which crash risk increases significantly, depending on the study methodology [Lin, *et al.* (1994); Frith (1994)]. A study of industrial fatigue in truck drivers found that, in more than 65 percent of cases, truck accidents took place during the second half of a trip, regardless of trip length [Mackie & Miller (1980)]. An analysis of Bureau of Motor Carrier Safety data in the 1970s found that about twice as many accidents occurred during the second half of trips than during the first half, regardless of trip duration [Harris (1978)]. Another study found that the risk of accident increased after the 4th hour of driving and peaked after 9 hours of driving [Kaneko & Jovanis (1992)]. These studies are among many finding that industrial fatigue plays a role in predisposing truck drivers to accidents.

Determining the magnitude of this effect, however, and ensuring that other factors (such as sleep history and time of day) have been factored out, is quite difficult. Ideally, perhaps, we would want to compare the number of serious crashes in the each hour of driving after an extended break to the total driving time by hour of driving or, alternatively, vehicle miles traveled by hour. Conceptually, the degree to which the distribution of crashes falls into later driving hours relative to the distribution of driving would indicate the change in risk for longer trips. The data

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[12] See previous section entitled “The Biology of Sleep” for further discussion of the circadian effect.

set would have to be reasonably representative of the drivers affected by the regulations; large enough to provide an accurate picture for individual hours, despite the rarity and randomness of crashes and the relatively small fraction of driving in the later hours; use an unbiased measure of hours; and cover a period in which long driving hours were legal. Furthermore, data on other factors that are known to affect fatigue and crash risks – total time on duty that day and previous days, short breaks, opportunities for restorative rest, time of day, and experience, for example – would have to be included in the data set as well, to allow the TOT effect to be isolated.

A data set meeting these criteria is not available at this time. There are some large samples of crash data that include the number of hours of driving, including the LTCCS and TIFA; but the time periods these cover are largely or entirely before the HOS rules were changed in 2003. They are also deficient, to varying degrees, in the availability and reliability of information on driver schedules and other factors that affect crash risks. Even more seriously, these studies do not directly provide information on the distribution of all driving by hour for either the drivers involved in the crashes or for comparable drivers. In other words, the data sets provide the numerator for the rate of crashes per hour, but not the denominator.

It is possible to develop distributions of all driving by hour (through surveys, for example), but these cannot be used along with crash data for a different population without biasing the results to an unacceptable degree. FMCSA is currently sponsoring a study based on schedule data collected by electronic logs that should be able to solve most of the problems in this type of research, but that study is not complete as of the time of this analysis.

Researchers have long asked how long a person can sustain work effort at different tasks without lengthy breaks, before his or her performance of those tasks becomes unacceptably degraded. There has always been a notion that, by itself, sustained performance at a task (TOT) eventually results in a "fatiguing effect," manifesting itself in the form of slower response times or errors of omission or vigilance. Below is a short literature review of five studies about the TOT effect on driving and some concluding remarks.

Jones & Stein (1987) attempted to provide "adjusted odds ratios" to different categories of "length of time in driving" (TOT), assigning a baseline value of 1.0 to the relative risk of the likelihood of crashes attributable to a driving time from 0 to 2 hours; and they presented an increased odds ratio of 1.2 for driving times from 2 to 5 hours and also 5 to 8 hours of driving time (TOT). The odds ratio for driving more than 8 hours was estimated at 1.7, but the work of Jones and Stein said nothing about projecting odds ratios for driving more than 9, 10, or 11 hours relative to driving more than 8, the root question of the entire discussion of truck driver HOS.

Lin, *et al.* (1993) introduced a time-dependent logistic regression model formulated to assess the safety of motor carrier operations. They described their model as being flexible, allowing the inclusion of time-independent covariates, time main effects, and time-related interactions. The model estimated the probability of having a crash at time interval t, subject to surviving (not having a crash) before that time interval. Covariates tested in the model in this paper included consecutive driving time, multiday driving pattern during a 7-day period, driver age and experience, and hours off duty before the trip of interest. Although the work of Lin, *et al.* (1993) has some appeal in the conduct of our study, their methods and modeling are of some concern in that they do not model beyond the 8-9 hours of driving incidents, something which is obviously needed to examine the HOS alternatives.

In their description of nine logistic regression modeling attempts, Lin, *et al.* (1993) stated that driving time (TOT) has the strongest direct effect on accident risk. The first 4 hours consistently have the lowest crash risk and are indistinguishable from each other. Accident (crash) risk increases significantly after the 4th hour of driving, by approximately 50 percent or more, until the 7th hour. The 8th and 9th hours show a further increase, approximately 80 percent and 130 percent higher than the first 4 hours. In a follow-on extension of the study conducted by Lin, *et al.* (1993), Park, *et al.* (2005) conducted a detailed analysis of preexisting crash and non-crash data representing an estimated 16 million vehicle miles of travel, which identified a persistent finding of increased crash risk associated with hours driving, with risk increases of 30 percent to more than 80 percent in later hours compared with the first hour of driving. These increases are somewhat more muted than the effects found in related earlier studies, such as Lin, *et al.* (1993), but provide further evidence that crash risk is higher in later hours of driving.

Campbell (1988) stated that there is a steady increase in the probability of accident involvement with the number of hours driving. To look into this, Campbell used data from accident reports filed with the Office of Motor Carriers and extracted the time of day that the accident occurred, the number of hours driving at the time of the accident, and the intended driving period had the accident not occurred. The accidents that were coded as the driver having dozed at the time of the accident were used to determine the TOT effect. The problem arises because not all of the crash data were included; crashes may have been caused by fatigue, yet the driver was not dozing at the time. It was concluded that the crossover point in which the proportion of accidents in the latter hours of driving is more frequent occurs around 4 hours of driving.

O'Neill, *et al.* (1999) studied the operating practices of CMV drivers, as well as the relationship of these practices to driver fatigue. Drivers worked a 14-hour on/10 hour off schedule, driving a simulator for a 5-day week. Two 30-minute breaks and a 45-minute lunch break were taken during the day at regularly scheduled times. The observed recovery effect of the breaks was rather striking. The effects of 6.5 hours of driving were virtually reduced to the starting levels by a 45-minute break [O'Neill, *et al.* (1999)]. It is important to keep in mind that, while this recovery effect is remarkable, it occurred under very strict, adhered-to conditions. This effect took place under daytime driving conditions, the 14 hours on/10 hours off driving schedule that allowed for adequate rest, and scheduled breaks. It cannot be said with a reasonable degree of certainty that this recovery effect would occur in the same way under different conditions.

The analysis of TOT effects presented below in the safety analysis relies primarily on similar methodology to that used in two more recent research efforts, one by Ken Campbell and one by a team led by Dr. Paul Jovanis at Pennsylvania State University [Campbell (2005); Jovanis, *et al.* (2005)]. Both efforts were undertaken specifically for FMCSA.

The Campbell analysis used national level data from the TIFA database for the years 1991-2002, comprising more than 50,000 truck-involved crashes [Campbell (2005)]. This database was developed from truck crashes in the National Highway Traffic Safety Administration Fatality Analysis Reporting System (FARS) database, with additional data on the driver and the carrier involved, compiled by the University of Michigan Transportation Research Institute after FARS data are published. Most importantly, the University of Michigan Transportation Research Institute added data on time since the driver's last 8-hour break, the truck and carrier types, and the planned trip length to the FARS data to create the TIFA database. Note that, because this data collection effort predates the 2003 rule change, the results reflect pre-2003 HOS regulations: driving time for interstate operations was limited to 10 hours, the minimum rest time between trips was only 8 hours, and there were no provisions for a restart of the cumulative 7/8 day duty period. Much of the driving after the 10th hour was by drivers who were breaking the law since it was illegal before 2003 for drivers engaged in interstate commerce to drive more than 10 hours in a work shift. These drivers' behavior might be expected to be generally riskier that those who follow the rules. However, the methodology used by this study controls for this effect. This study looked at fatigue-coded crashes as a share of all crashes that occurred in each hour. The denominator—all crashes that occurred during the 11th hour—should suffer from this same risky driver effect, and the effect should cancel itself out when looking at the relative proportion of fatigue-coded crashes during illegal hours of driving. Also,states have been allowed by 49 CFR 350.341(e)(1) to permit up to 12 hours of driving within a 16-hour window for drivers engaged in intrastate commerce. Because TIFA is a census of fatal crashes, and some fatal crashes involve drivers engaged in intrastate commerce, a portion of the 11th and 12th hour crashes occurred within legal intrastate commerce driving limits. The Campbell analysis addressed several aspects of the effect of driver fatigue on crash risk, including the fraction of crashes where fatigue was reported as the leading cause in FARS, the prevalence of fatigue by motor carrier industry segment, truck type, time of day, and hours of driving at the time of the crash. For the last of these analyses, a chart was provided of relative crash risk for each successive hour of driving. Relative crash risk for each hour is calculated as a multiple of the crash risk in the first hour. Exhibit 4-1 shows the results.

For example, for the 10th hour of driving, Exhibit 4-2 indicates that the relative risk per involvement in a fatigue-coded crash is roughly 2.5 times higher than in the first hour of driving (reading across to the vertical axis of the chart). In the 11th hour of driving, the relative risk per involvement in a fatigue-coded crash is roughly five times higher than that in the first hour. The first number above each bar chart represents the number of large trucks involved in *fatigue-coded fatal* crashes between 1991 and 2002 for each driving hour, while the second represents the total number of large trucks involved in *all fatal* crashes within that same driving hour. For example, within the 11th hour of driving, there were 9 large trucks involved in fatigue-coded fatal crashes between 1991 and 2002, while there were 94 large trucks involved in all fatal crashes during that same driving hour. The figures above each chart help to provide a better understanding of the prevalence of large truck fatal crashes in each driving hour, in that they reveal that as driving hours increase, the number of fatal crashes, as well as fatigue-coded fatal crashes, generally decrease in a steady fashion.

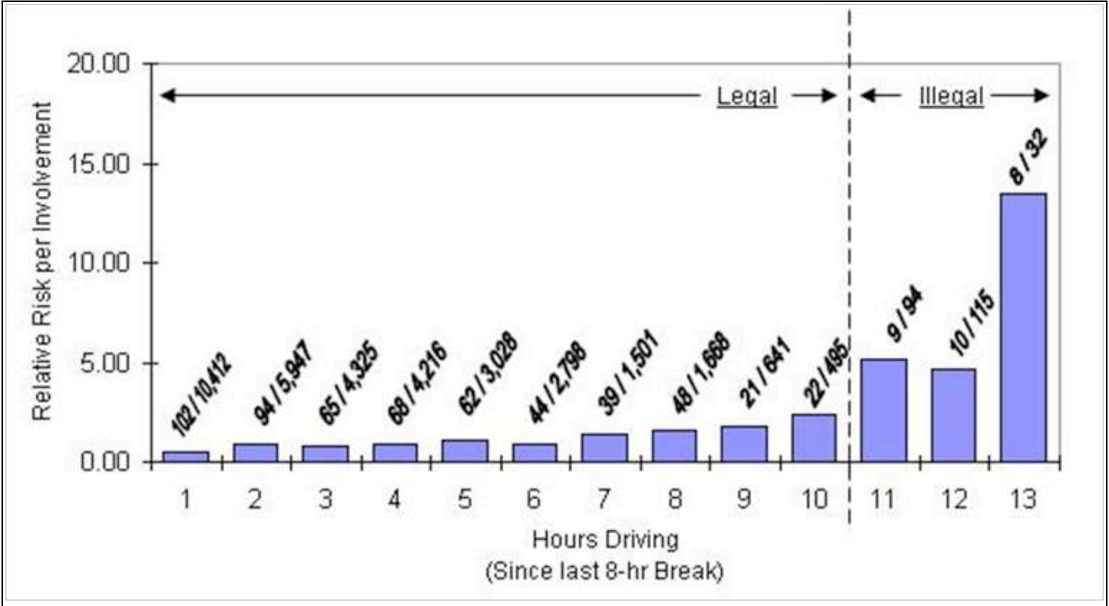

Exhibit 4-1. Relative risk of fatigue involvement – TIFA.

NOTE: Numbers above each bar chart represent the number of large trucks involved in fatigue crashes and total fatal crashes, respectively.

Data Source: Trucks Involved in Fatal Accidents (TIFA), 1991-2002.

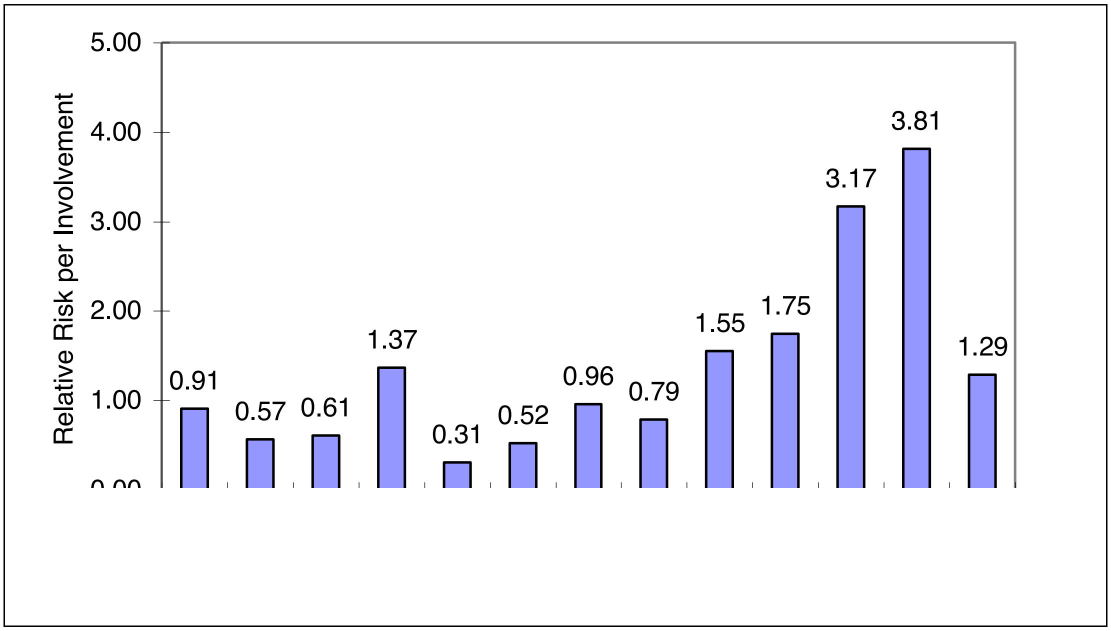

Exhibit 4-2. Relative fatigue-involvement risk by driving time – LTCCS data.

Campbell followed this analysis with a similar analysis of data from the LTCCS [Campbell (2005)]. These data covered the period April 1, 2001 to December 31, 2003 and contain a sample of nearly 1,000 crashes. The result of the driving time analysis is shown in Exhibit 4-2 above. The overall result is similar to that derived from the TIFA data, although relative fatigue involvement factors for hours exceeding 10 hours represented by the LTCCS data appear to be lower than from TIFA data. The preliminary LTCCS data include injury crashes as well as fatal crashes, and it is not clear whether the relative risk data includes the injury crashes.

In contrast to the Campbell analysis, the Penn State/Dr. Paul Jovanis analysis relied on a sample of logbook data obtained from three cooperating LTL carriers, as described in the report to FMCSA [Jovanis, *et al.* (2005)]. The sample included 7-day driver records for 231 crashes and comparable data for 462 similar periods without a crash. The sample periods were randomly selected. All the data obtained were calendar year 2004, after the introduction of the revised HOS regulations which permitted an 11th driving hour and required longer breaks between on duty periods. The sample of commercial operators driving in the 11th hour was very small, with the data limited to 34 drivers. TOT task effects were calculated for the entire sample and for different subsets of the data, including operations with team drivers and sleeper berths, and different start times and shift patterns.

The result for all industry segments and driving routines combined is shown in the following Exhibit 4-3. The main limitation with this analysis is that it is representative of only one trucking industry segment (LTL carriers). Additionally, there are very few driver cases involving 11 hours of driving (34, which includes both crash and non-crash cases), which is presumably causing the very high variance surrounding the estimated 11th hour crash risk. The data show an 11th hour risk factor of about 3.4, which would be substantially higher than the equivalent estimates derived from the Campbell - LTCCS data discussed above because it refers to all crashes rather than to fatigue crashes only. The Jovanis 2005 study also reported that the

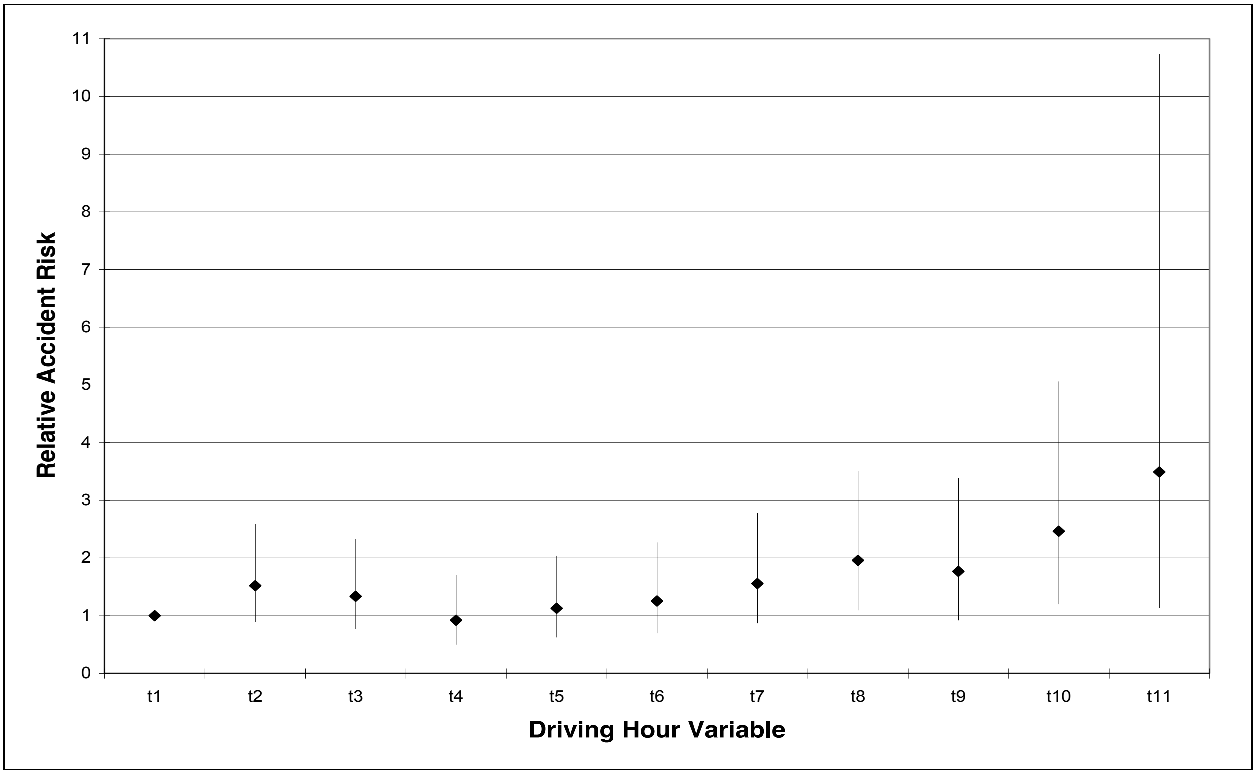

Exhibit 4-3. Relative crash risk with driving time (Jovanis Sample of LTL Operation).

results are comparable to results obtained from a similar analysis of data gathered in the 1980s [Park, *et. al.* (2005)].

To address the sample size and LTL focus issues of the Jovanis 2005 study, FMCSA sponsors a larger and broader study using the same basic approach. In April 2011, Pennsylvania State University completed a quantitative study of the safety implications of driver HOS using a case-control time-dependent logistic regression methodology [Jovanis, *et al.* (2011)]. The Pennsylvania State University study team collected data from the logs of drivers who were in crashes that involved either a fatality, an injury requiring medical treatment away from the scene of the crash, or a tow-away. The drivers' logs covered a periods of 2 weeks prior to the crash and were compared to a random sample (two drivers) of non-crash-involved drivers selected from the same company, terminal, and month using a case-control logistic regression formulation. Data from 1,564 drivers were collected. The methodology employed by the team had been peer-reviewed in many previous research studies [Jovanis, *et al.* (1991); Kaneko & Jovanis (1992); Lin, *et al.* (1993); Lin, *et al.* (1994)]. The data were separated into TL and LTL analyses because previous research indicated differences in the factors contributing to crashes for these two segments of the trucking industry. In total, 878 drivers (318 crash-involved and 560 controls) were analyzed in TL operations and 686 drivers (224 crash-involved and 462 controls) were analyzed in LTL operations. For the LTL operations, the study found that as driving time increased so did the odds of being in a crash. Analysis of LTL data shows a strong and consistent pattern of increases in crash odds as driving time increases. The highest odds are in the 11th hour. Additionally, the TL models revealed associations between some multiday driving patterns and increased crash risk with driving times in the 7–11-hour range. TL drivers who drive during the day have increased odds of a crash with long driving hours.

4.2.2 Naturalistic Driving Study

Finally, the Agency sponsored naturalistic driving studies. A study conducted by Hanowski, *et al.* (2009) involved outfitting trucks with monitoring equipment and then examining the data on critical incidents and crashes to determine, among other things, whether the number of safety critical events (SCEs) — defined here as crashes, near crash events, or crash relevant conflicts — increases with increased hours of driving in a given day. This study, which resulted in more than 2 million driving miles of continuously collected data, calculated the relative frequency (critical incidents divided by opportunities) for each hour of driving and determined odds ratios from this data. Analyses found an elevated risk in the first driving-hour, but no consistent significant difference between hours 2 through 11. Analyses on time-of-day, where incident rates were calculated for each of the 24 hours in the day, were also conducted. The results found a strong positive correlation with national traffic density data.

Though driver performance in the Hanowski study was assessed through the occurrence of critical incidents instead of crashes (as is used in many of the previous studies), the Agency believes that, in general, an increase in critical incidents is a reasonable measure of some increase in crash risk. There were only a few crashes in this study and relatively few critical incidents in the 10th and 11th hours. In addition, the study (and most other studies) did not account for breaks taken during the workday, for total duty time on the day of the crash or incident, or duty time during that week, all of which may affect fatigue at any particular hour. Finally, the Hanowski study did not consider on-duty hours in addition to driving hours, so it was not possible to know whether the first hour of driving came early in the day, or at the end of long day.

To address some of the issues with the Hanowski study that made it difficult to draw conclusions about TOT, FMCSA sponsored a follow-on study by the same research team. In April 2011, Virginia Tech Transportation Institute (VTTI) completed a naturalistic driving study that examined the activities performed in the 14-hour workday and investigated the relationship between SCEs and driving hours, work hours, and breaks [Blanco, *et al.* (2011)]. The study's methodology was similar to that employed by VTTI in other studies conducted in support of HOS rulemaking and driver fatigue research. The data acquisition system was composed of five main components: an encased unit that housed the computer and external hard drive; dynamic sensors; vehicle network; incident box; and five video cameras. This data acquisition suite included improved technology that allowed VTTI to provide a more accurate and reliable measure of lane tracking. A custom-developed state-of-the-art lane tracking system was developed by VTTI and included in the data acquisition system. The lane tracking system consisted of a single analog black-and-white camera, a personal computer with a frame grabber card, and an interface-to-vehicle network for obtaining ground speed. The system reported the distance from center of truck to left and right lane markings (average error less than 2 inches). The system accurately and reliably measured and stored data when the vehicle crossed the dashed or solid highway lines. Lane tracking has historically been shown in the research to be a good measure of functional impairment due to driver fatigue [Pilutti, *et al.* (1995); Stein (1995)].

Unlike previous naturalistic driving research that had shown no time-on-task effect, this study showed statistically significant positive relationship between driving time and the number of SCEs (shown in Exhibit 4-4). As discussed in Section 4.4, below, the magnitude of this relationship is comparable to that used in the benefits analysis in this RIA. This finding is

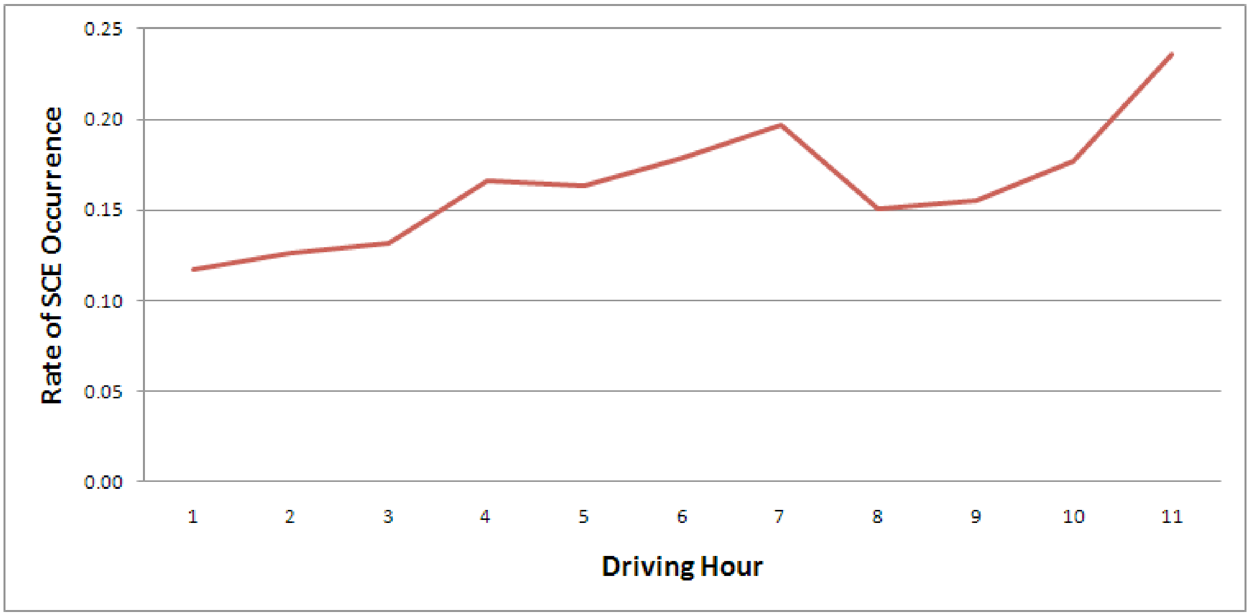

Exhibit 4-4. Rate of SCE occurrence by driving hour (Blanco sample of TL and LTL operations).

particularly important because in past HOS rulemakings, the Agency has relied heavily on naturalistic driving research as the basis for increasing driving time from 10 to 11 hours per day. The Blanco study showed that naturalistic driving research no longer contradicts other types of driving time research conducted using different methodologies. The studies are all now consistent in showing that as the number of driving hours increase so does the number of crashes or SCEs. Although the study found a statistically significant and positive trend of increasing safety critical events as hours of daily driving increase, a statistically significant difference was not found between the 11th hour and the 10th or other later hours in the day. Statistically significant differences were found between the number of SCEs in the 11th hour and the number of SCEs in earlier hours of the day.

The Blanco study also showed that when non-driving activities (both work- and rest-related) were introduced during the driver‘s shift—creating a break from the driving task—these breaks significantly reduced the risk of being involved in an SCE during the 1-hour window after the break. The benefits of breaks from driving ranged from a 30 to 50-percent reduction in risk of SCEs (depending on the type of break from driving), with the greatest benefit occurring for off-duty (non-working) breaks.

The Blanco study evaluated driving hours based on whether the hour occurred at the beginning, middle, or end of an on-duty shift. The first 5 hours after coming on duty were categorized as the beginning of the on-duty shift. By definition, any hour after the 5th hour of driving could not fall within this work period. Hours 6-9 were categorized as the middle shift hours, and hours 10-14 were categorized as the end of shift hours. Driving hours 10 hours and beyond could occur only during end of shift hours, by definition. The first hours of driving (hours 1-5) could occur in any shift period depending on how much on-duty not driving and break time a driver incorporated into a day. For example, if a driver spent 7 hours loading a truck at the beginning of a day, the 1st hour of driving would be in the middle shift hours, and if that driver drove 3 hours, the third hour would be in the end of shift hours.

Analysis of SCEs showed that, in general, the same hour of driving had more SCEs if it occurred at the end of a shift than if it occurred at the beginning or middle of a shift. For example, the 5th hour of driving, if it occurred at the beginning of a shift, had 0.11 SCEs per unit of exposure. This same hour of driving had 0.20 SCE per hour of exposure if it occurred in the middle of a shift, and 0.21 SCEs if it occurred at the end of a shift. For the 8th and 9th hours, if they occurred in the middle of a shift there were 0.09 and 0.10 SCE per unit of exposure respectively. At the end of the shift, by comparison, the 8th and 9th hour of driving had 0.22 SCE and 0.18 SCE per unit of exposure respectively. This finding indicates that the interaction of total shift length and driving time impairs safety performance later in the day, suggesting strongly that safety would be negatively affected by allowing driving after 14 hours on duty have elapsed.

4.3 EVALUATING CRASH RISK FOR EACH HOUR OF DRIVING

Given the widely varying rates in the estimate of risk by hour of driving, the Agency used the data available to estimate a function that relates the risk of a fatigue-involved crash to each hour of driving. This analysis most closely parallels Campbell's analysis of the TIFA data. We present our methodology here and then describe how we used it to evaluate a portion of the safety benefits associated with this rule below. We conclude by comparing our estimated TOT functions to those from several of the studies reviewed above, before using the function to estimate safety benefits.

4.3.1 Data Analysis and Methodology for Estimating the TOT Function

The goal of the analysis is to find the change in fatigue-related crash risks that would result from eliminating driving in the 11th hour. Assuming motor carriers will still deliver the same volume of freight, even without the 11th hour, we can presume that driving not done in the 11th hour will be done by additional drivers, in somewhat shorter trips. There will still be crashes in those shorter trips; indeed, there will still be fatigue-related crashes in these shorter trips. What must be calculated, then, is the average fatigue-related crash rate in trips that allow the 11th hour compared to the rate in the replacement trips that do not.

The analytical approach to adding an explicit TOT effect to the fatigue model is to determine a functional relationship between TOT and the measured percentage of crashes attributable to fatigue, relative to typical fatigue levels, and to use that relative risk to scale up the overall fatigue crash risk for driving hours with above-average fatigue percentages. All estimated fatigue crash risks are then scaled in such a way as to yield an average fatigue crash risk of 13 percent under baseline conditions, which is the rate projected for LH driving in the LTCCS.

To derive a functional relationship between TOT and the percentage of crashes caused by fatigue, FMCSA has, in the past, used TIFA data from 1991 through 2002. For each TOT level from the 1st hour through the 12th, FMCSA computed the average percentage of crashes caused by fatigue. As TOT increased, the data showed a strong increase in the ratio of fatigue-coded crashes to all crashes. The approach to estimating the effects of long driving hours on crash risks assumes that higher ratios of fatigue-coded crashes to total crashes imply higher crash rates. It is mathematically possible, though, that the increase in this ratio comes about because the denominator falls as driving hours increase, not because fatigue increases. In other words, falling rates of crashes due to weather, mechanical failure, traffic, or road conditions, as each driver accumulates more hours on the road, could make it appear that fatigue is a growing problem, whereas it is actually stable. The Agency has no evidence, however, for a pattern in which greater hours on the road would be associated with systematic reductions in crash causes other than fatigue. Another problem with the approach of using the increase in fatigue-coded crashes as a measure of the TOT effect is that the determination of fatigue involvement is somewhat subjective. Accident investigators may be more likely to code crashes as fatigue-related if the driver has been on the road longer or if it is late at night, thus fatigue coding, could be influenced by knowledge of drivers' schedules or the time of day on the part of the person coding the factors related to a crash. Extremely few data points were available for TOT levels beyond 12. The original analysis modeled the TOT relationship as a cubic function, which appeared to fit the data well. To make it possible to use this function with limited data without introducing unreasonable variability for the estimated fatigue percentage at high TOT levels, the TOT and fatigue percentages for the crashes beyond 12 hours are averaged among all the crashes: the average percentage of fatigue-coded crashes for these 101 crashes was 24.75 percent, and the average TOT was 16.73 hours.

4.3.2 Use of an Estimated Function

The decision to fit a function to the data, rather than use the average probabilities of fatigue-coded crashes seen in the data, is a reasonable choice given the very small amount of data at high TOT levels. A review of the TIFA data from 1991-2002 shown in Exhibit 4-5, helps to illustrate this point. The 1991-2002 data give, for each hour of driving, the total number of crashes and the total number of crashes that were deemed fatigue-coded. For example, in the eleventh hour of driving, there were a total of 94 crashes, of which 9 crashes (9.57 percent) were fatigue-coded. The relationship between the number of hours of driving and the probability that a crash in that hour is fatigue-coded provides the basis for the estimation.

For many of the TOTs, the observed proportion of crashes that were fatigue-coded is not a good estimate of the long-run probability of future crashes being fatigue-related. If the probability of a fatigue-related crash is low and the total number of observed crashes is relatively small (say, a few hundred or less), then the observed proportion will be a poor estimate of the true proportion because the observed proportion will have a large variance. This is shown by the last four columns in Exhibit 4-5, which give 95 percent and 99 percent confidence intervals for the true proportions based only on the observed proportions at the same hour.

Exhibit 4-5. 1991–2002 TIFA Crash Data Showing Confidence Intervals

TOT (Hour of Driving)	Total Fatigue-Coded Crashes	Total Crashes	Percentage of Crashes That Were Fatigue-Coded	95% Confidence Interval for Percentage*		99% Confidence Interval for Percentage[a]	
				Lower	Upper	Lower	Upper
1	102	10412	0.98%	0.80%	1.19%	0.75%	1.26%
2	94	5947	1.58%	1.28%	1.93%	1.19%	2.05%
3	65	4325	1.50%	1.16%	1.91%	1.07%	2.05%
4	68	4216	1.61%	1.25%	2.04%	1.16%	2.18%
5	62	3028	2.05%	1.57%	2.62%	1.44%	2.81%
6	44	2798	1.57%	1.14%	2.11%	1.03%	2.28%
7	39	1501	2.60%	1.85%	3.53%	1.66%	3.85%
8	48	1668	2.88%	2.13%	3.80%	1.93%	4.10%
9	21	641	3.28%	2.04%	4.96%	1.74%	5.54%
10	22	495	4.44%	2.81%	6.65%	2.40%	7.40%
11	9	94	9.57%	4.47%	17.40%	3.42%	20.05%
12	10	115	8.70%	4.25%	15.41%	3.31%	17.70%
13	8	32	25.00%	11.46%	43.40%	8.66%	48.92%
14	0	17	0.00%	0.00%	19.51%	0.00%	26.78%
15	1	10	10.00%	0.25%	44.50%	0.05%	54.43%
16	3	10	30.00%	6.67%	65.25%	3.70%	73.51%
17	2	6	33.33%	4.33%	77.72%	1.87%	85.64%
18	1	6	16.67%	0.42%	64.12%	0.08%	74.60%
19	0	2	0.00%	0.00%	84.19%	0.00%	92.93%
20	0	3	0.00%	0.00%	70.76%	0.00%	82.90%
21	1	2	50.00%	1.26%	98.74%	0.25%	99.75%

Exhibit 4-5. 1991–2002 TIFA Crash Data Showing Confidence Intervals

TOT (Hour of Driving)	Total Fatigue-Coded Crashes	Total Crashes	Percentage of Crashes That Were Fatigue-Coded	95% Confidence Interval for Percentage*		99% Confidence Interval for Percentage[a]	
				Lower	Upper	Lower	Upper
22	1	2	50.00%	1.26%	98.74%	0.25%	99.75%
23	0	1	0.00%	0.00%	97.50%	0.00%	99.50%
24	1	2	50.00%	1.26%	98.74%	0.25%	99.75%
28	2	2	100.00%	15.81%	100.00%	7.07%	100.00%
31	0	1	0.00%	0.00%	97.50%	0.00%	99.50%
34	3	3	100.00%	29.24%	100.00%	17.10%	100.00%
36	2	2	100.00%	15.81%	100.00%	7.07%	100.00%

[a] Calculation of confidence intervals use a binomial model of fatigue probabilities for each TOT.

These confidence intervals are based on the fact that the distribution of the number of fatigue-coded crashes at hour h of driving is a binomial distribution, where the number of trials, n, is the total number of crashes at hour h, and the "success" probability is the long run probability that a crash at hour h was fatigue-coded. This assumes that the n crashes occurred independently. For example, at h = 11, the observed percentage was 9/94 = 9.57 percent and the 95 percent confidence interval is the wide range from 4.47 percent to 17.40 percent. For hours 10 and under, the total number of crashes is much higher and the confidence intervals are much narrower; but for 15 or more hours of driving, when the number of observations drops off drastically, the intervals are very wide.

Thus, relying on the percentage of fatigue crashes for individual TOT hours would subject the analysis to great uncertainty, because random factors can cause large changes in measured percentages of small numbers. The data for the 13th hour, for instance, shows 25.00 percent fatigue crashes, while the 14th hour shows 0 percent fatigue; the 11th hour shows 9.57 percent, while the 12th shows only 8.70 percent. Clearly, none of these disparate values are themselves precise measures of what would be seen if enough data were available. Much better predictions of the probabilities of crashes being fatigue-related can be obtained by the standard statistical approach of fitting parametric statistical models to all the data, so that the probability is a smooth function of the TOT. In this manner the probabilities can be estimated more precisely, and can be estimated for all values of h, not just the values in the data. For example, we can use interpolation to estimate the probability for 25, 26, and 27 hours of driving, which were not included in the data set but were within the range of driving hours in that set. The need to fit a function to the data, using the data from the large volumes of crash experience at low TOT levels, was in fact recognized by the appeals court in the 2004 decision.[13]

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[13] United States Court of Appeals for the District of Columbia Circuit, argued April 13, 2004, decided July 16, 2004, No. 03-1165, Public Citizen, *et al.*, Petitioners *v.* Federal Motor Carrier Safety Administration, Respondent, p. 16.

4.3.3 Estimation of the TOT Function

We have estimated the function using the following approach, which seems appropriate given the nature of the data: A logistic model was used to predict fatigue involvement probabilities for each hour of driving, also described as the TOT. This approach replaced the use of the cubic function and obviated the need to combine data points at high TOT levels. Logistic regression is a standard statistical approach that ensures that the predicted probabilities will be between zero and one. The logistic regression takes the form

$$\mathrm{Logit}\{\mathrm{Prob}\ (\text{Crash is fatigue-coded} \mid \text{crash occurred at hour } h \text{ of driving})\} = a0 + a1\times h + a2\times h^2 + a3\times h^3 + \ldots + ak\times h^k,$$

where k >= 0 is some integer and the coefficients a0, a1, …, ak are unknown parameters. The logit function is defined as

$$\mathrm{Logit}(p) = \log\{p/(1-p)\},$$

where log denotes the natural logarithm.

We fitted this model to the 1991-2002 data using the method of maximum likelihood. The value of k was found by a sequential procedure under which terms $ak\times h^k$ were added to the model until the score chi-square statistic for the added term was not statistically significant at the 5 percent level. The selected model was a quadratic model with k = 2:

$$\mathrm{Logit}\{\mathrm{Prob}\ (\text{Crash is fatigue-coded} \mid \text{crash occurred at hour } h \text{ of driving})\} = a0 + a1\times h + a2\times h^2.$$

The estimated parameter values and their standard errors are shown in Exhibit 4-6. The standard error is the estimated standard deviation of the estimated coefficient.

Exhibit 4-6. Fitted Logistic Model to 1991–2002 Data

Parameter	Estimated Value	Standard Error
a0	-4.6342	0.0911
a1	0.1226	0.0265
a2	0.0034	0.0016

Using the logistic model, the probabilities that a crash is fatigue-coded can be estimated for any value of h. The predicted probabilities for h <= 20 and their 95 percent confidence intervals are given in Exhibit 4-7. One obvious feature of this model is that the predicted probabilities of crashes being fatigue-coded increase as the TOT increases, which is the expected pattern assuming that increased TOT leads to increased fatigue and therefore a greater chance of a crash attributable to that fatigue; the observed probabilities often do not follow this pattern.

Note that the observed percentages of fatigue-coded crashes often are not included in the 95 percent confidence intervals for the predicted percentages. For example, for h = 11, the observed percentage is 9.6 percent but the 95 percent confidence interval for the predicted percentage ranges from 4.51 percent to 6.25 percent. The predicted results are nonetheless consistent with the observed data because of the large uncertainty in the observed percentages, as shown in Exhibit 4-5. The following Exhibit 4-8 demonstrates this point by comparing the confidence intervals for the observed percentages with the confidence intervals for the predicted percentages greater than the range h = 9, 10, 11, 12, 13, and 14. Except for h = 13, the confidence intervals for the observed percentage contain the confidence intervals for the predicted percentage.

Exhibit 4-7. Confidence Intervals for Percentages of Crashes that were Fatigue-coded Using the Logistic Model Applied to 1991–2002 TIFA Data

TOT (Hour of Driving)	Observed Percentage of Crashes that were Fatigue-coded	Predicted Percentage of Crashes that were Fatigue-coded	95% Confidence Interval for Predicted Percentage Lower	Upper
1	0.98%	1.09%	0.95%	1.25%
2	1.58%	1.24%	1.12%	1.38%
3	1.50%	1.43%	1.30%	1.56%
4	1.61%	1.65%	1.51%	1.79%
5	2.05%	1.91%	1.75%	2.09%
6	1.57%	2.24%	2.03%	2.47%
7	2.60%	2.63%	2.36%	2.93%
8	2.88%	3.11%	2.75%	3.51%
9	3.28%	3.70%	3.23%	4.23%
10	4.44%	4.42%	3.81%	5.12%
11	9.57%	5.31%	4.51%	6.25%
12	8.70%	6.41%	5.35%	7.67%
13	25.00%	7.77%	6.33%	9.50%
14	0.00%	9.44%	7.49%	11.83%
15	10.00%	11.49%	8.85%	14.80%
16	30.00%	14.00%	10.41%	18.58%
17	33.33%	17.05%	12.22%	23.29%
18	16.67%	20.72%	14.29%	29.06%
19	0.00%	25.06%	16.64%	35.92%
20	0.00%	30.11%	19.28%	43.73%

Exhibit 4-8. Comparison of 95% Confidence Intervals for Observed and Predicted Percentages Using 1991–2002 Data

TOT (Hour of Driving)	Observed Percentage of Crashes that were Fatigue-coded	95% Confidence Interval for Observed Percentage Lower	Upper	Predicted Percentage of Crashes that were Fatigue-coded	95% Confidence Interval for Predicted Percentage Lower	Upper
9	3.28%	2.04%	4.96%	3.70%	3.23%	4.23%
10	4.44%	2.81%	6.65%	4.42%	3.81%	5.12%
11	9.57%	4.47%	17.40%	5.31%	4.51%	6.25%
12	8.70%	4.25%	15.41%	6.41%	5.35%	7.67%
13	25.00%	11.46%	43.40%	7.77%	6.33%	9.50%
14	0.00%	0.00%	19.51%	9.44%	7.49%	11.83%

Exhibit 4-9 displays these concepts graphically; the bars show the 95 percent confidence intervals for the fatigue-coded percentages in individual hours.[14]

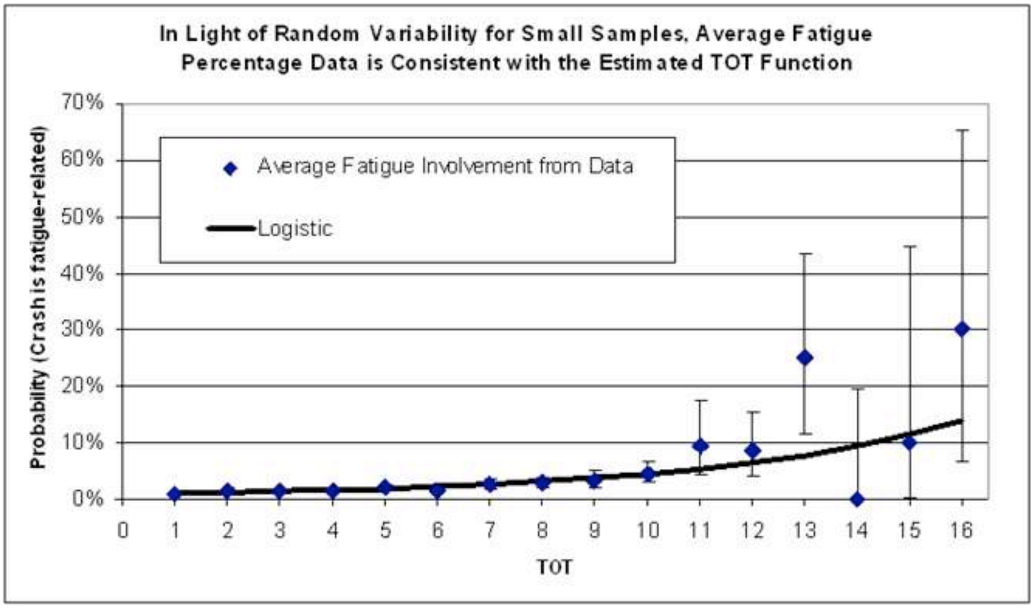

Exhibit 4-9. Comparison of logistic TOT function to confidence bounds around fatigue percentages.

4.3.4 *"Bootstrap" Analysis of the Difference in Predicted Probability for Hour 11 and Mean Predicted Probability for Hours 1 to 10*

The predicted probabilities in Exhibit 4-8 can be used to calculate the difference between the mean probability for hours of driving 1 to 10 and the probability for hour 11, which is a measure of the change in fatigue-coded crashes that would occur if an hour of driving were shifted from the 11th hour to an average of the earlier hours. The mean probability for hours of driving 1 to 10 equals 2.34 percent and the probability for hour 11 equals 5.31 percent, giving a difference of 2.97 percent (5.31% – 2.34%). Because this estimated difference is a complicated function of the parameters a0, a1, and a2, the uncertainty of the estimated difference cannot be calculated analytically. For this calculation we used a bootstrap simulation technique, as described below.

The raw data contain results for a total of 35,341 crashes (not including cases with missing values for TOT or fatigue), of which 10,412 occurred in hour of driving 1, 5,947 occurred in

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[14] The relationship between TOT and fatigue seen in these data might be related, in part, to difference in sleep, work, and time awake, which are in turn correlated with TOT. Unfortunately, the data set on which this analysis was based did not include information on these other variables, so it was not possible to determine the independent effect of TOT, holding other variables constant. Because some of the apparent effect of TOT is likely to be due to these other variables, we consider the functional relationship used here to be a conservative measure of the size of the independent effect of TOT (in that the function is likely to overstate that effect). Also, to the extent that the 2003 HOS increased opportunities to sleep and reduced opportunities to drive after long hours awake, the current relationship of TOT to fatigue might be weaker than it appears here. As discussed further below, using data collected after 2003 does reduce the TOT effect, but to a small degree only.

hour of driving 2, and so on. For each of 1,000 bootstrap simulations, we used the fitted logistic model to simulate the 35,341 crashes, deciding for each crash whether or not it was fatigue-coded. Thus for the first simulated crash in the first hour of driving, the logistic model predicts that the probability of being fatigue-coded equals 1.09 percent, so this crash is given a 1.09 percent probability of being fatigue-coded. Similar calculations are made for the remaining 10,411 crashes in the first hour of driving. Thus the simulated number of fatigue-coded crashes in the first hour of driving has a binomial distribution with 10,412 trials and “success” probability 1.09 percent. A similar calculation applies to all the other crashes in this first bootstrap simulation giving a total of 35,341 simulated crashes (either fatigue-coded or not fatigue-coded). The logistic model with $k = 2$ is fitted to the simulated data and the predicted difference between the mean probability for hours of driving 1 to 10 and the probability for hour 11 is calculated for this fitted model. This procedure is repeated for 1,000 bootstrap simulations, producing 1,000 estimated differences ranging from 1.93 percent to 4.03 percent. Standard statistical theory shows that this distribution of 1,000 differences will be a good approximation to the true uncertainty distribution of the difference. Therefore, as shown in Exhibit 4-10. we can estimate a 95 percent confidence interval for the difference as the range from the 26th highest difference to the 975th highest difference, which was 2.32 percent to 3.65 percent, because there are 25 + 25 = 50 differences (50/1000 = 5.00%) outside of this range. Similarly we can estimate a 99 percent confidence interval for the difference as the range from the 6th highest difference to the 995th highest difference, 2.15 percent to 3.91 percent, because there are 5 + 5 = 10 differences (10/1000 = 1.00%) outside of this range.

Exhibit 4-10. Bootstrap Confidence Intervals for the Probability of a Crash Being Fatigue-coded in Hour 11 Minus the Mean Probability of a Crash Being Fatigue-coded for Hours 1 to 10

Estimate	95% Lower Bound	95% Upper Bound	99% Lower Bound	99% Upper Bound
2.97%	2.32%	3.65%	2.15%	3.91%

As mentioned previously, one difficulty with measuring the risk of driving by hour using TIFA data is the lack of crash and exposure data by driving hour. TIFA data provides a reasonably good estimate of the number of fatal crashes that occur in each hour of driving, but does not measure how much driving occurs in each hour. Thus, TIFA data alone cannot provide an estimate of the risk of crashes per hour of driving.

4.4 DETAILED EXPLANATION OF THE ESTIMATION OF SAFETY BENEFITS

This section explains more specifically how the safety functions described above are used to quantify and monetize the changes in crash risks resulting from the options. The step-by-step explanation of how the numbers are developed is based on the first of the three regulatory alternatives (Option 2), but the method applies to the others as well. To calculate the safety benefits of the new HOS rule provisions, we use the same categorization of drivers that we use in the calculation of the costs of operational changes. The calculation of safety benefits also involves the average changes in driving hours per week, as estimated in the previous chapter as part of the estimation of the cost of operational changes.

The safety benefits of the HOS rule changes can be broken down into two effects: the benefits of the restriction on daily driving time and the cumulative effect on the hours worked per week. To estimate the benefit of the reduction in daily driving time, we use the reduction in hours for each category of drivers that was calculated in the previous chapter on operational changes. A slightly different calculation is used for the purpose of estimating the safety benefits. In the previous chapter, when the total hours lost due to the restriction of driving to 10 hours were calculated, a portion of the impact was subtracted to avoid double-counting the impact of the restriction in daily work time. For the estimate of the safety impacts of eliminating the 11th hours of driving, the issue of double-counting does not apply: all of the 11th hours of driving in each driver's week are eliminated (though some of them can be shifted to another day, turning an 8-hour day into a 9-hour day). The number of affected 11th hours per week can thus be found by multiplying the percentage of tours of duty with 11th hours by the number of tours of duty per week. For example, for the high intensity drivers, this calculation results in a total of 1.50 hours affected per week (25% × 1 hour × 6 tours). This calculation is repeated for each category of drivers to obtain the total reduction of hours of driving in the 11th hour due to the 11th hour restriction, per driver (see Appendix D).

Next, the total lost hours due to the 11th hour restriction is multiplied by the percentage that each driver category comprises of the total driver population and by 50 weeks per year to obtain the annual total hours affected (that is, lost or reallocated to another workday) for each driver category. For example, for the high intensity drivers, this resulted in a total of 14.25 hours (1.5 × 19% × 50) affected per year per driver. For each category of drivers, we repeat this calculation and sum them to obtain a total of 56.25 hours affected per year per driver due to the 11th hour restriction. We then multiply this total by the total number of drivers to obtain a total of 90 million (56.25 hours × 1,600,000 drivers) hours lost per year due to the 11th hour restriction.

In calculating the hours affected due to the 11th hour restriction, we also account for the fact that some of that time could be shifted to another day of driving. For each of the categories of drivers, the total hours affected per year per driver are multiplied by the percent of an hour which that group of drivers would be able to shift to another day. The total hours lost for the moderate, high, very, and extreme intensity groups are multiplied by 0.45, 0.35, 0.25, and 0.15, respectively, based on our judgments about the fraction of driving done in the 11th hour that could be made up by shifting it to another day. The totals for the different driver groups are summed to obtain the total number of hours shifted to another day. We then divide the sum of the hours shifted to another day by the sum of the total hours lost to determine the percentage of hours shifted relative to the hours lost. This results in an estimated total of 68 percent of the baseline driving in the 11th hour that is lost due to the 11th hour restriction, rather than being shifted to another driving day.

The total of hours lost due to the 11th hour restriction is then multiplied by the per-hour safety benefit due to eliminating driving in the 11th hour. There are several steps involved in calculating the per-hour benefit of eliminating driving in the 11th hour. The first step is to calculate the excess risk of crashes for driving in the 11th hour, relative to driving in the hours that would replace the driving that can no longer be done in the 11th hour. This step recognizes, explicitly, that virtually the same amount of freight would need to be delivered, whether or not 11 hours of driving are allowed; and, therefore, there would be increases in driving in other hours in response to a prohibition on the use of the 11th hour. To the extent that existing drivers are not able to shift some driving to another workday, we assume that the lost driving hours are reallocated to an added driver either in the same or a different carrier. That added driver is assumed to drive a typical mix of hours up to, but not beyond, 10 hours per day (the assumed limit) – that is, driving 5 hours as often as existing drivers do so, driving 9 hours as often as existing driver do so, and so forth. Because the hours shifted to added drivers would be a typical mix of hours 1 through 10, we assume that the risk of a fatigue-related crash would be no different from the risk of a fatigue-related crash when no more than 10 hours are permitted. The per-driving-hour reduction in the risk of fatigue is then the risk of fatigue in the 11th hour by itself minus the typical level of fatigue.

Our estimate of the risk of fatigue in the 11th hour is based on an assumed average level of fatigue involvement in crashes, combined with a TOT function (discussed below) that expresses how fatigue involvement changes with hours of driving. The average level of fatigue involvement is uncertain, largely due to the difficulty of accurately measuring fatigue. For this analysis, our baseline level of fatigue involvement in crashes is based on the LTCCS data. This data was collected during the 2001-2003 calendar years.

In comparing fatigue involvement with other data sources, it is important to examine the proportion of single vehicle crashes in the data, because fatigue is overrepresented in single vehicle crashes. The LTCCS is an example of this phenomenon. Truck driver fatigue was coded as a factor in 13 percent of all crashes in the LTCCS, but was a factor in 28 percent of single vehicle truck crashes. To confirm that single vehicle crashes are not overrepresented in LTCCS, we compare the percentage of single vehicle crashes in LTCCS data with the percentage of single vehicle crashes recorded in FARS data for the same years. Single vehicle truck crashes make up 21 percent of the LTCCS crashes, and 17.5 percent of the FARS crashes from the same years. Given the small difference in these percentages, it appears that single vehicle crashes may be slightly overrepresented in LTCCS, but within what would be considered the margin of error.

Another factor that militates against fatigue being overrepresented in LTCCS is that LTCCS crash investigators took a very conservative approach to coding crash factors. LTCCS investigators coded crash factors as unknown when no cause of the crash could be determined. As a result, 13.24 percent of crashes recorded in LTCCS were coded as having an unknown cause. Presumably, a portion of these crashes were caused by fatigue, even though fatigue could not be identified definitively as a contributing factor by the crash investigator. Given the conservative approach to coding crash causes and the relatively small difference in single vehicle crashes included in LTCCS compared to FARS data from the same years, we are reasonably confident that the fatigue involvement rate in LTCCS is accurate. Because these figures are estimates, we have considered a range of fatigue involvement in conducting the safety benefit analysis for this rule. A lower value of 7 percent is employed in sensitivity analyses, based on the 8.15 percent value found though a careful reanalysis of TIFA data conducted for the RIA for the 2003 HOS rule and projected fatigue reductions under the 2003 HOS rule. A higher value of 18 percent is also used for sensitivity analysis, chosen to be roughly as far above the LTCCS value of 13 percent as the 8.15 percent pre-2003 estimate is below 13 percent. We are confident that the range of baseline fatigue involvement, from 7 to 18 percent, is reasonable given the evidence we have from FARS, LTCCS, and other data sources.

As discussed above, a logistic TOT function was estimated for the RIA for the 2007 HOS rule, using data from TIFA for the years 1991 through 2002 (when only 10 hours of driving were allowed for interstate operations). This function (shown below in Exhibit 4-11 and described above in section 4.3) was presented in the RIA for the 2007 HOS rule, and showed the 11th hour with a 5.31 percent chance of fatigue, compared to an industry-wide average below 2 percent. Thus, the chance of fatigue in the 11th hour is more than twice as great as in the average hour.

Exhibit 4-11. Fitted Logistic Model to 1991–2007 Data

Parameter	Estimated Value	Standard Error
a0	-4.80834	0.077051
a1	0.164463	0.020058
a2	0.000405	0.00105

For this analysis, we have re-estimated the TOT function using additional TIFA data for the years 2003 through 2007, in combination with the data from 1991 through 2007. Exhibit 4-11 presents the parameters for this updated model. Exhibit 4-12 shows the original and the updated TOT functions on the same graph; they differ only slightly.

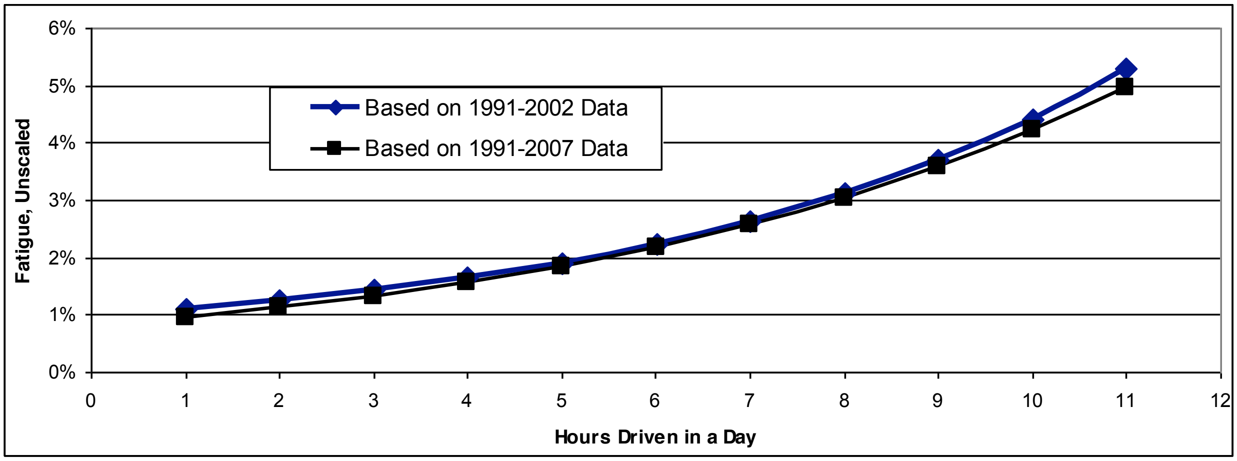

Exhibit 4-12. Percent of fatigue involvement in crashes by hour of driving (showing 2007 function and the newer function).

It should be noted, however, that using a fitted curve derived from both pre- and post-2003 data somewhat masks the differences in data from these two periods. Exhibit 4-12 demonstrates this difference. There is a relatively large difference between these periods in the 11th hour, for which driving was mostly illegal before 2003, although the general trend of increasing fatigue coding is present in both series. Also, differences of the same or larger relative magnitude are observed in earlier hours (e.g. the 2nd and 5th) that were legal under both rules. In other hours fatigue-coding was greater in the 2004-2007 than in the pre-2003 series. This exhibit indicates that 11th-hour risk of fatigue-coded crashes was considerably lower post 2004, although this may be random variation because relatively few crashes are fatigue coded in any given year.

The risk in the average hour was calculated using the updated logistic TOT and a distribution of driving hours based on the 2005 FMCSA Field Survey. This analysis showed a fatigue involvement rate of 1.81 percent for average driving patterns. Knowing that TIFA is likely to understate fatigue involvement, we scale the fatigue percentage upward for each hour so that the average fatigue involvement equals 13 percent (in the central case) and either 7 or 18 percent (in the sensitivity cases).

Our function provides a risk estimate for later hours of driving that is larger than that found in the Hanowski, *et al.* (2009) study (described above), which showed no difference in risk by hour of driving, except that the first hour was found to have a higher crash involvement rate than other hours. In the Hanowski study, the other hours were indistinguishable from one another with regard to crash risk. By contrast, our function is highly consistent with the more recent Blanco, *et al.* (2011), which used the same method as Hanowski, *et al.* (2009). The results of Blanco, *et al.* (2011) provide clear evidence that there is a statistically significant rise in the risks related to crashes as driving hours increase. A strong trend is seen across all shifts. A somewhat weaker trend, but one which is similar and still significant using a one-tail test (which is the correct statistical approach to use if there are very strong reasons to believe that long hours of driving would not improve performance), is seen even for the smaller set of data that go into the 11th hour.[15] That latter trend shows that risk in the 11th hour is about 36 percent higher than the risk in the first hour (i.e., [(0.1379 + 11 × 0.0052) / 0.1379 + 1 × 0.0052) = 1.36]). That is actually a stronger effect than would be seen based on our baseline time-on-task function used here, scaling the fatigue crashes to 13 percent (which is [(1 + 36.1%) /(1 + 7.4%) = 1.27]). Given that both of these functions are uncertain because they are based on statistical estimation, however, these values are entirely consistent.

The Jones and Stein, and Park and Jovanis studies found significantly higher risk associated with later hours of driving than the function we estimated from the TIFA data. We applied this methodology to the LTCCS data as well, following the Campbell analyses described above, and produced results comparable to those obtained from the TIFA data. Considering the various functions available from the research, our TOT effect appears to be reasonable in size.

After scaling up the TOT function to yield a higher average, it predicts a 36.15 percent likelihood of fatigue involvement in the 11th hour when the average fatigue risk is 13 percent. The scaled function is shown in Exhibit 4-13. Shifting an hour from the 11th to a typical driving hour is, therefore, assumed to reduce the fatigue crash risk for the affected hour by 23.15 percent (36.15% – 13%). Similar calculations are made for the lower and upper fatigue sensitivity cases.

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[15] Tests of statistical significance are used to determine whether a parameter estimate could have taken a value at least as high as it appears to be, simply due to random variability in the data. A standard “two tail” test is used if the parameter could be either positive or negative, and takes account of both “tails” or extremes of the distribution of a random variable. A “one-tail” test is appropriate if there are strong reasons to think that the true value of the parameter cannot have one particular sign – e.g., if the true value cannot be negative. In this case, because there are good reasons to believe that, if time on task has any effect on driving performance that effect is deleterious, a one-tail test is appropriate for assessing whether the time-on-task effect found in the Blanco study is significant.

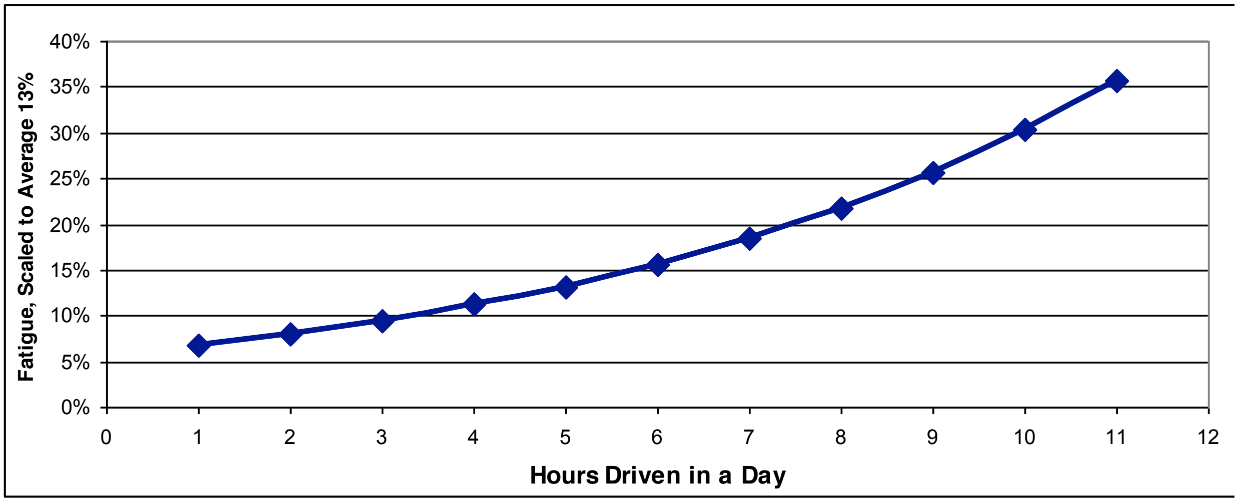

Exhibit 4-13. Percent of fatigue involvement in crashes by hour of driving (scaled function).

A slightly different calculation is made to estimate the reduction in risk for hours that a given driver can shift to another day. These driving hours would be, in essence, added to the end of a driving day that would otherwise have been of typical length for that driver.[16] Driving days can be of various lengths, but for the hard-driving individuals, who are most affected by a driving hour limit, they are likely to be relatively long. We assume, for simplicity, an equal mix of driving days from 5 to 9 hours long, so that the shifted hour would fall between the 6th hour and the 10th hour. The average TOT risk for adding driving in these hours would be above that for the typical hour; by applying the logistic TOT function to these hours (after scaling it up to average 13% fatigue), we estimate their risk to be 21.92 percent. Thus, shifting an hour of driving from the 11th hour (with a projected fatigue risk of about 36.15 percent) to another day (with a projected risk of about 21.92 percent) would reduce the crash risk by 36.15 percent minus 21.92 percent, or 14.23 percent.

The next step is to calculate the value of these reductions in fatigue crash risk per hour by multiplying by the average level of costs of heavy-duty truck crashes per hour of driving. To calculate this number, we start with the estimated cost of all LH crashes of $37.3 billion (2008$) (based on an estimate of almost 434,000 large truck crashes, the estimated average damages of $148,000 per crash, and an estimate of the fraction of large truck crash damages associated with the LH industry [FMCSA (2002a)]).[17] We then divide this number by the estimated number of

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[16] One could also think of this hour of driving being added to the beginning of the next day, but then the driving that would have been done in the first hour of that next day would be pushed into the second hour, and the second hour into the third, and so forth for the rest of the day. From either perspective, the net effect will be an increase in driving at the end of a typical day of driving.

[17] The long-haul segment accounts for approximately 58 percent of large truck crash damages, as calculated in the 2003 RIA [FMCSA (2002a)]. The total number of crashes and cost per crash is taken from FMCSA, Excel file "CrashCostTableTool.xls."

LH drivers (1,600,000) and also by the average hours driven per year per driver (2,030).[18] This calculation results in an average crash cost per hour of driving of $11.49.

Once we calculate the average crash cost per hour of driving, we next calculate the value per hour of the change in risk from removing the 11th hour. This value per hour is calculated for two different scenarios: the restricted 11th hour of driving being reallocated to a new driver, and the restricted 11th hour of driving being shifted to another driving day by the same driver. For calculating the value per hour of the change in risk when the restricted 11th hour of driving is reallocated to a new driver, we first determine the change in the percentage of fatigue involvement when the restricted 11th hour of driving is reallocated to a new driver. The change in the fatigue level is thus the scaled percent of fatigue involvement in the 11th hour (36.15 percent) minus the average percent fatigue involvement for all other hours (13 percent), or 23.15 percent (36.15% – 13.00%). We next multiply this change in the percent fatigue involvement by the average crash cost per hour of driving. This results in a value of $2.66 (23.15% × $11.49) per hour of the change in fatigue risk from removing the 11th hour when the restricted driving is reallocated to another driver.

We repeat this calculation for the second scenario where the restricted 11th hour driving is shifted to other days by the same driver. We make a similar calculation for the change in fatigue level, except for this calculation we use the average percent fatigue involvement for hours 6 through 10 of driving time, assuming that the driver would shift the time to the end of one of his or her other driving days. For this scenario, the change in fatigue level is thus the scaled percent fatigue involvement in the 11th hour (36.15 percent) minus the average percent fatigue involvement for hours 6 through 10 (21.92 percent), or 14.23 percent (36.15% – 21.92%). We next multiply this change in the percent fatigue involvement by the average crash cost per hour of driving. This results in a value of $1.63 (14.23% × $11.49) per hour of the change in fatigue risk from removing the 11th hour when the restricted driving is redistributed to other days by the same driver.

Now that we have an estimated value per hour of the change in risk from removing the 11th hour for both of the possible scenarios discussed above, we calculate the weighted value per hour of the change in risk. For this calculation, we use the percentage of the restricted 11th hour of driving that would be lost and redistributed to another driver, rather than shifted to another day by the same driver, which is calculated above (68 percent). We obtain the weighted value per hour of the change in crash risk by taking the sum of the value per hour for hours that are lost and redistributed to another driver ($2.66) multiplied by the assumed percent of hours for this scenario (68 percent) and the value per hour for hours that are shifted to another driver ($1.63) multiplied by the assumed percent of hours for this scenario (100% - 68% = 32%). This calculation results in a weighted value per hour of the change in fatigue risk of $2.34 ([$2.66 × 68%] + [$1.63 × 32%]). This weighted value per hour of the change in fatigue risk is then multiplied by the hours per year lost due to the 11th hour restriction, calculated above (90 million), to obtain a total of $210 million for the safety benefit due to the change in daily driving time. (This value is shown for Option 2 in Exhibit 6-5, for the 13 percent fatigue scenario.)

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[18] The average hours driven per year is the product of hours driven per week (40.60) multiplied by the weeks worked per year (50).

Similar calculations are made using the lower and upper bound fatigue estimates. These other estimates scale in proportion to the estimate shown above with the median fatigue value.

Next, we estimate the safety benefits due to the change in weekly work time. The first step of estimating the safety benefits of reducing weekly work time is to determine the weekly work time for each category of drivers if the new HOS rule were in effect. For each category of drivers, we start with the assumed average work time, as shown in Exhibit 2-6, and subtract from it the change in weekly work time as calculated in Chapter 3, section 3.2. Under Option 2, for example, the estimated change in its weekly work time for the high intensity group (1.01 hours) is subtracted from its average weekly work time (60 hours) to obtain a new average weekly work time of just under 59 hours. This change in weekly work time involves a shift in hours per week from an existing driver to another driver driving a typical schedule. As these hours are shifted, the fatigue rate drops from the rate for the driver whose hours have been cut to the rate for a driver at a typical fatigue level.

Next, for each total weekly work time, the number of average hours worked is converted to a fatigue percentage using a cumulative fatigue function estimated using data from the LTCCS. This function is based on the dashed curve in Exhibit 4-14, which is a logistic function relating hours worked in the previous week to the likelihood that the truck driver in a crash was judged to be fatigued [FMCSA (2008c), p.12]. This cumulative function is scaled so that the risk for a typical driver, estimated to work about 52 hours per week, has a typical fatigue level (in the central case, of 13 percent). For example, a weekly work schedule of 60 hours per week is associated with a 16.61 percent fatigue level. This is compared to the fatigue level of 13 percent for a driver with an average schedule of 52.10 hours per week (as described in the industry profile section; the scaled function is also shown in Exhibit 4-14, as the solid curve). We take the difference of the old average weekly work time for each category of drivers and the weekly work time for a typical driver to obtain a difference of 3.61 percent (16.61% – 13.00%). We

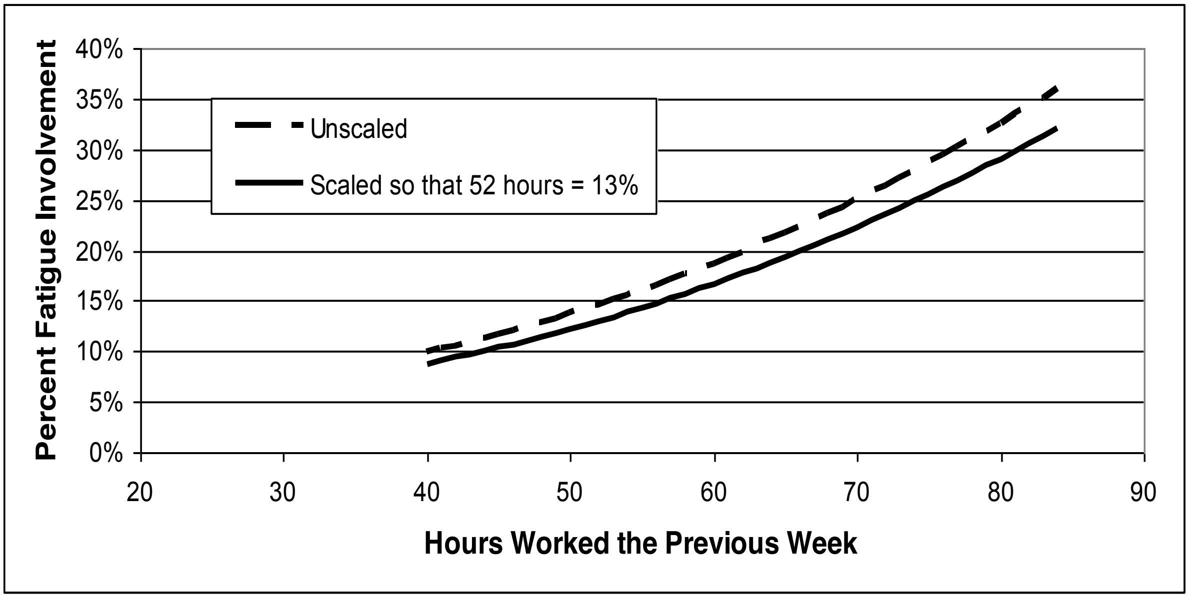

Exhibit 4-14. Percent fatigue involvement by weekly work time (scaled and unscaled).

next use the average crash cost per hour of working to determine the value of the change in crash risk for the reduction in crash risk that results from redistributing hours to drivers working less intense schedules. We estimate the average cost per hour of working by multiplying the average cost per hour of driving ($11.49) by the average hours driven (40.60) divided by the typical hours worked per week (52.10) for a cost per hour of working of $8.95 ($11.49 × 40.60 / 52.10)[19] For example, for the high intensity drivers, the $8.95 average crash cost per hour of working is multiplied by the reduction in weekly work time for this group (1.01 hours) and by the percent reduction in fatigue that results from a driver working an intense schedule versus a driver working an average schedule (3.61 percent). This calculation results in a value of $0.33 for the reduction in weekly working time due to redistributing hours from a driver working an intense schedule to one working an average schedule. This calculation is then repeated for each category of drivers.

We next estimate the value of drivers reducing their own risk in the following week by driving less intense schedules. For this calculation, we use the average weekly work time if the new HOS rule were in effect, which was calculated above. In Option 2 for example, for drivers with a high intensity schedule, this results in a new weekly average work time of 59 hours (60 hours – 1.01 hours). We then use the data on the percent fatigue for each hour of driving to determine the fatigue level associated with the change in hours from the original weekly average work time to the average weekly work time if the new HOS rule were in effect. For example, for drivers with a high intensity schedule, this results in a change in fatigue of 0.50 percent (16.61% – 16.12%). Recognizing that all hours of driving would have a lower risk of fatigue, this change in the percentage of fatigue is multiplied by the new average weekly work time and then by the average crash cost per hour of driving to obtain the value of this reduction in fatigue. For example, for the high intensity drivers, this results in a benefit of $2.63 per week (0.50% × 59 × $8.95) due to the reduction of the individual driver's own fatigue level. This calculation is repeated for each category of drivers (see Appendix D).

To determine the total safety benefit for the change in weekly work time for the different driver categories, the values of these two different safety effects from the change in weekly work time are summed. For example, for the high intensity drivers, this results in a total hourly benefit that rounds to $2.95 ($0.33 + $2.63) per week. We next convert this weekly value to an annual value by multiplying by 50 weeks of work per year. For example, for the high intensity drivers, this results in an annual safety benefit of about $148 ($2.95 × 50) per driver in this category. We then repeat this calculation for each category of drivers (see Appendix D).

To obtain the total safety benefits for the change in weekly work time, we then multiply the annual safety benefit per driver by the total number of drivers in each category. For example, there are an estimated 304,000 (1,600,000 × 19%) high intensity drivers. Multiplying this number of drivers by the annual per driver safety benefit of $148 results in a total safety benefit for this category of drivers of $45 million. This calculation was repeated for each category of drivers, and the resulting values were summed to obtain a total safety benefit estimate of

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[19] Average hours worked per year is calculated as shown in Exhibit 2-6.

$390 million for the reduction in weekly work time. (This value is shown for Option 2 in Exhibit 6-5, for the 13 percent fatigue scenario.)

Lastly, we calculate the total safety benefits by summing the total safety benefits resulting from the change in daily driving time ($210 million) and the total safety benefits resulting from the change in weekly work time ($390 million). This results in total safety benefits of $600 million under the median assumption for the percent fatigue involvement. (This value is shown for Option 2 in Exhibit 6-5.)

5. Methodology for Valuing Health Benefits

Chapter 5 presents our methodology for estimating the health benefits of the new HOS rule. These benefits result from reductions in mortality risk due to the decreases in total duty time in a day and in a week, and thus possible increases in sleep. Although there are other health impacts mitigated by reductions in long work hours and related increases in sleep, such as improvements in many chronic health problems, reduction in mortality risk was the impact that was most easily quantifiable. Another possible impact of long work hours is the foregone earnings that would result if a driver were to develop a medically disqualifying condition and reductions in driver-associated health care costs. Other than this qualitative discussion, we do not consider the possible benefits of reductions in medically disqualifying conditions or health care cost reductions in this analysis. In this chapter, we first present an overview of our methodological approach, and then we present a detailed description of the methodology for estimating the health benefits of the new rule, and how that methodology has changed in response to comments.

5.1. OVERVIEW OF HEALTH IMPACT METHODOLOGY

As discussed in detail in the literature review on health impacts found in Appendix B, there are numerous pathways between the extreme numbers of hours per day and week allowed under existing rule and important health endpoints. For instance, long work hours are often linked to insufficient sleep, obesity, and cardiovascular disease. In turn, these associations with long work hours are commonly linked to other health outcomes—insufficient sleep is associated with obesity, high blood pressure, and diabetes; obesity is linked to obstructive sleep apnea, high blood pressure, cardiovascular disease, stroke, diabetes, arthritis, and other diseases. Although the biochemical basis for these pathways is generally understood, it is not possible to link the relatively small changes in work hours that will occur under the rule to changes in the health impacts to develop a quantitative estimate of the health benefits that could result from a given change in the HOS rule. The difficulty of doing quantitative analyses, though, does not mean that potential health benefits must be left aside. Instead, FMCSA believes that it is worth choosing one of the direct pathways, and building a quantitative link between HOS rule provisions and health benefits.

One of the simplest and most robust of the pathways runs from excessive hours of work, through reduced average sleep, to increases in mortality. There is a growing scientific consensus that there is a U-shaped relationship between average sleep per night and mortality rates, meaning that the further one's average sleep falls below (or above) an ideal value (of between 7 and 8 hours per night) the greater the chance of death at any given age. This sleep-mortality relationship is based on epidemiological studies, and does not in itself demonstrate causality (i.e., the epidemiology research itself does not prove that increasing sleep will cause reduced mortality). This lack of causality in the sleep-mortality research, however, does not mean it should be ignored. There are many well-explored pathways from sleep deprivation to the kinds of health impacts that would increase mortality rates; reduced sleep produces chemical changes that have been causally related to the risk of diabetes, cardiovascular disease, inflammation (linked to cancer risk), and obesity, all of which cause increased mortality. Because of the curvature of the relationship, the impact on mortality rates per lost hour of sleep also increases the further a person falls below the ideal. This curvature means that changing average sleep makes very little difference for individuals – such as truck drivers working normal schedules –

who are able to get nearly ideal amounts of sleep. On the other hand, having the chance to get slightly more sleep per night can be crucial for the health of those drivers working so hard that they are usually sleep deprived.

The data used to demonstrate this U-shaped relationship are taken from three large-scale, long-term studies [Amagai, *et al.* (2004); Ferrie, *et al.* (2007); Tamakoshi & Ohno (2004)]. For the analysis of sleep and mortality we performed a National Library of Medicine PubMed search using the following terms: sleep; rest; nap; circadian rhythm; parasomnia; insomnia; dyssomnia; hypersomnia; mortality; death; lifespan; years of life; and lifeyears. Search limits set were: search on title/abstract, publication date in past 10 years, human (non-animal) studies, English language. We also searched Google using the same set of keywords. We identified a number of studies of sleep duration and mortality. We selected only three for the final analysis because the three studies were the only ones that included information on the size and demographic makeup of the sample, the crude mortality rate (in person-years), and the confidence interval for risk of increased mortality in males and females.[20]

Amagai, *et al.* (2004) followed 11,325 participants spanning several years in a "population-based prospective study investigating risk factors for cardiovascular diseases started in 1992. The authors report "A total of 495 deaths … were observed during the average of 8.2-year follow-up period. After adjusting for age, systolic blood pressure, serum total cholesterol, body mass index, smoking habits, alcohol drinking habits, education, and marital status, the hazard ratios (95% confidence intervals) of all-cause mortality for individuals sleeping shorter than 6 hours and 9 hours or longer were 2.4 (1.3-4.2) and 1.1 (0.8-1.6) in males, and 0.7 (0.2-2.3) and 1.5 (1.0-2.4) in females, respectively, relative to those with 7-7.9 hours sleep" [Amagai, *et al.* (2004), p.124].[21]

Ferrie, *et al.* (2007) followed 10,308 white-collar British civil servants in a prospective cohort study, with follow-up at 12 and 17 years. The authors report finding "U-shaped associations … between sleep (≤5, 6, 7, 8, >9 hours) at Phase 1 and Phase 3 and subsequent all-cause, cardiovascular, and non-cardiovascular mortality" [Ferrie, *et al.* (2007), p.1659]. The "U-shaped curve" represents the frequent finding that deviations toward less sleep or more sleep than 7-8 hours increases an individual's risk of early mortality. Tamakoshi, & Ohno (2004) enrolled 104,010 individuals in a study of cancer risk in rural Japanese residents, followed them for approximately 10 years, and found that for this sample, "Sleep duration at night of 7 hours … [showed] the lowest mortality risk" [Tamakoshi & Ohno (2004), p.51].

Mapping these values on a graph results in a U-shaped curve in which 7 hours of sleep carries the lowest hazard ratio, and sleep periods of less than 7 and more than 7 hours show a progressively larger mortality hazard ratio. The process of estimating the equation is discussed in the next section.

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[20] A further meta-analysis published in 2010, added additional studies for a total of 1.38 million subjects and 112,000 deaths, and found a slightly higher relative risk for short sleep [Cappuccio, *et al.* (2010)].

[21] For hazard ratios and odds ratios, if a confidence interval does not include 1, the result is statistically significant. For example, an odds ratio of 2 with a confidence interval of .8 to 3 is not statistically significant; and an odds ratio of 1.2, with a confidence interval of 1.1 to 1.5 is significant.

The link from work hours to sleep is also strong. In 2002, FMCSA developed an empirical relationship between reported hours of work and measured hours of sleep for a sample of truck drivers during a period of several weeks [Balkin, *et al.* (2002)]. That relationship (shown in Exhibit 5-1) showed drivers getting just more than 8 hours of sleep on their days off. Working a few hours on a given day had little effect on average sleep, but as the hours of work climbed, the drop in sleep per hour accelerated; at 12 hours of daily work the drivers in the sample were getting less than 7 hours of sleep, and each additional hour of work cut sleep by more than a fifth of an hour. Data on drivers from the American Time Use Survey showed little more than 6.5 hours of self-reported sleep (which is known to be overstated) at 12 hours of work, with an even steeper rate of decline per hour of extra work.[22]

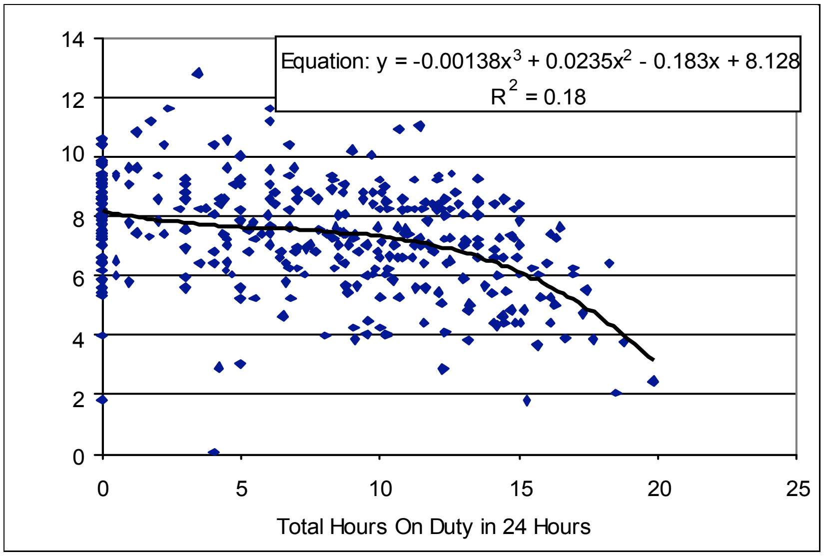

Exhibit 5-1. Effects of duty hours on sleep.

Putting together the relationship of greater hours of work leading to steadily worsening sleep loss, and the relationship of sleep loss to steadily worsening mortality rates, it appears that small cuts in the maximum permissible duty hours could have health benefits that result in substantial reductions in mortality rates for the affected drivers. On the other hand, these same relationships imply that cutting hours for more typical drivers would have a much more limited benefit, because each hour of work prevented would have a smaller effect on sleep, and each added increment to sleep would have a minimal effect on mortality.

Because of the uncertainty involved in the relationships between work hours and health, and the uncertainty about baseline conditions, FMCSA is not able to produce a precise health benefit estimate. But this kind of analysis can at least show the potential magnitude of the impacts of cutting back some of the longest work weeks. As developed below, it appears that the measurable health benefits of reducing the maximum hours of work allowed per week could well be as great as the costs, and the other pathways (which have not been included in the quantitative analysis) could add even further to these benefits.

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[22] Data extracted from 2008 American Time Use Survey database, available from the Bureau of Labor Statistics for Census Code 9130, Drivers/Sales Workers and Truck Drivers.

5.2. DETAILED EXPLANATION OF THE ESTIMATION OF CHANGES IN DRIVERS' HEALTH

To estimate the impact of the HOS rule change on expected mortality risk, we used the four divisions of drivers discussed in Chapters 2 and 3. These four divisions categorize drivers by average hours worked and are identified as follows: moderate intensity (average weekly work time of 45 hours), high intensity (60 hours), very high intensity (70 hours), and extreme intensity (80 hours). Each group has a calculated change in hours worked, which is also described in Chapter 3. Furthermore, for this analysis, we used low, medium, and high baseline levels of sleep to analyze the impacts of changes in hours worked on expected mortality risk to obtain a range of possible health impacts from changes in hours worked. For example, for the very high intensity group, the base hours slept for this category with a low baseline level of sleep is 6.28 hours per night, based on measured sleep for drivers in a naturalistic driving study and an assumption that these drivers were working at a high but not extreme intensity level.[23] For the higher baseline sleep assumption for this same group we entered our estimates of their average daily hours on duty into the work/sleep function based on the Walter Reed Field Study (described above) [Balkin, *et al.* (2002)]. The medium sleep level for this group was the average of the high and low estimates. We repeated this process for the other groups of drivers, using the predictions of the work/sleep relationship described above for the high sleep assumptions, and basing the differences between the high, low, and medium sleep levels on the differences found for the very high intensity group. Exhibit 5-2 shows our estimates on the change in work hours that would result from the HOS rule changes and our judgments (described above) on the baseline level of sleep for each category of drivers.

The first step in estimating the change in expected mortality risk is to determine the hours of sleep gained under the rule. For this calculation, we obtain the difference between the work/sleep function evaluated at the projected hours of work per day under the HOS Option and the baseline hours worked per day. For the very high intensity group, for example, the hours projected under Option 2 was about 11.24 hours, which is equal to the baseline hours worked per day of 11.67 minus 0.43. Thus, the hours of sleep gained under the rule is expressed as follows:

$$\text{Change in sleep} = (-0.00138 \times W^3 + 0.0235 \times W^2 - 0.183 \times W + 8.128)$$

$$- (-0.00138 \times B^3 + 0.0235 \times B^2 - 0.183 \times B + 8.128)$$

where W is the daily work hours after the rule change, and B is the daily work hours under the baseline.[24]

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[23] This may be a conservative assumption as the drivers in the Hanowski *et al.* (2007) study do not appear to have been working this hard. In addition, the average is for a limited dataset and includes days off; the average across the whole dataset was a slightly lower, 6.15 hours per night including days off. Most of the drivers, however, were driving at night, which would lower overall sleep.

[24] The equation relating hours of sleep and hours of work is $y = -0.00138x^3 + 0.0235x^2 - 0.183x + 8.128$ where y is the number of hours slept and x is the number of hours worked. This function was estimated using data on the numbers of hours worked and the number of hours slept for long-haul drivers.

Exhibit 5-2. Changes in Hours Worked per Day and Baseline Levels of Sleep by Driver Group

Driver Group	Baseline Sleep	Change in Hours Worked Per Day – Option 2	Change in Hours Worked Per Day – Option 3	Change in Hours Worked Per Day – Option 4	Baseline Level of Sleep (Hours)
Extreme	Low	-1.50	-1.50	-1.50	5.87
	Medium	-1.50	-1.50	-1.50	6.23
	High	-1.50	-1.50	-1.50	6.59
Very High	Low	-0.43	-0.13	-0.89	6.28
	Medium	-0.43	-0.13	-0.89	6.64
	High	-0.43	-0.13	-0.89	7.00
High	Low	-0.14	-0.01	-0.48	6.55
	Medium	-0.14	-0.01	-0.48	6.91
	High	-0.14	-0.01	-0.48	7.27
Moderate	Low	-0.04	0	-0.17	6.66
	Medium	-0.04	0	-0.17	7.02
	High	-0.04	0	-0.17	7.38

For the very high intensity group with low baseline sleep, for example, this calculation (carried out to an appropriate level of precision) yields an estimate of 0.08 hour of sleep gained. In turn, the total hours slept after improvement is the sum of the base hours slept per night and the total hours of improvement in sleep. For the very high intensity group with low baseline sleep, this calculation results in 6.36 hours (6.28 hours + 0.08 hour) of sleep per night under the Option 2. For Option 3 this calculation results in 6.30 hours (6.28 hours + 0.02 hour) of sleep, and for Option 4 the calculation results in 6.44 hours (6.28 hours + 0.16 hour) of sleep.

The next step in the calculation of health benefits was to translate the increased sleep due to the HOS rule changes into decreased mortality risk. This relationship was estimated by regressing mortality on the expected value of hours of sleep and the expected value of hours of sleep squared [Social Security Administration (2006)].[25] The statistical analyses of the Phase 1 sleep-hours data in the Ferrie study (shown in the first five rows of Exhibit 5-3) was complicated by the fact that the subjects' average hours of sleep was reported as categories (e.g., less than 6, 6, 7, etc.) that appeared to map to intervals (for example we assumed that a response of "6" really means 5.5 to 6.5 hours, rather than exactly 6). To convert these intervals into a point representing all of the subjects in that interval, we fitted a normal distribution to the "hours of sleep" frequency distribution presented in the first phase of the Ferrie study and obtained a mean

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[25] The equation relating mortality and the expected value of hours of sleep is $y = 11.7603 - 3.1377x + 0.2274x^2$ where y represents mortality and x represents the expected value of hours of sleep.

of 6.787 hours and a standard deviation of 0.768 hour. We used this distribution to find the expected level of sleep for subjects in each interval.

Exhibit 5-3. Sleep – Mortality Risk Ratios (Ferrie, *et al*. 2007)

Sleep Hours: From	Sleep Hours: To	Frequency	Observed Mortality Ratio	Sleep Hours: Midvalue	Expected Hours: exph	Expected Hours Squared: exphh	Predicted Mortality Ratio	Standard Error
Data points from Ferrie, *et al*. 2007:								
0	5.5	587	1.61	2.75	5.18	26.94	1.62	0.06
5.5	6.5	2642	1.11	6	6.10	37.31	1.10	0.04
6.5	7.5	4884	1	7	6.97	48.68	0.95	0.05
7.5	8.5	1579	1.08	8	7.85	61.65	1.15	0.04
8.5	12	89	1.77	10.25	8.77	76.93	1.74	0.06
Fitted points assuming sleep is normally distributed:								
0.5	1.5			1	1.39	1.95	7.83	0.66
1.5	2.5			2	2.37	5.63	5.60	0.44
2.5	3.5			3	3.34	11.16	3.83	0.27
3.5	4.5			4	4.29	18.42	2.50	0.14
4.5	5.5			5	5.21	27.21	1.60	0.06
5.5	6.5			6	6.10	37.31	1.10	0.04
6.5	7.5			7	6.97	48.68	0.95	0.05
7.5	8.5			8	7.85	61.65	1.15	0.04
8.5	9.5			9	8.75	76.66	1.73	0.06
9.5	10.5			10	9.69	93.90	2.71	0.14
10.5	11.5			11	10.65	113.38	4.13	0.28
11.5	12.5			12	11.62	135.02	6.00	0.45
Fitted points assuming subjects sleep discrete numbers of hours:								
1	1			1	1.00	1.00	8.85	0.76
2	2			2	2.00	4.00	6.39	0.52
3	3			3	3.00	9.00	4.39	0.32
4	4			4	4.00	16.00	2.85	0.17
5	5			5	5.00	25.00	1.76	0.07
6	6			6	6.00	36.00	1.12	0.04
7	7			7	7.00	49.00	0.94	0.05
8	8			8	8.00	64.00	1.21	0.04
9	9			9	9.00	81.00	1.94	0.08
10	10			10	10.00	100.00	3.12	0.18
11	11			11	11.00	121.00	4.76	0.33
12	12			12	12.00	144.00	6.85	0.53

To regress the mortality hazard ratios we calculated ‘exph’ and ‘exphh,’ the expected number of hours of sleep and the expected number of hours squared for each interval. Thus if the hours value is exactly N, then exph = N and exphh = N*N. We then regressed the published estimated mortality ratio versus exph and exphh (and an intercept). This gives predicted values for the mortality ratio if the hours of sleep value is exactly N (an interval from N to N) or if the hours of sleep is reported as N, but is assumed to lie inside the interval from N-0.5 to N+0.5 and comes from the fitted normal distribution. The model is shown below. The two approaches give very similar predictions, as shown in Exhibit 5-4.

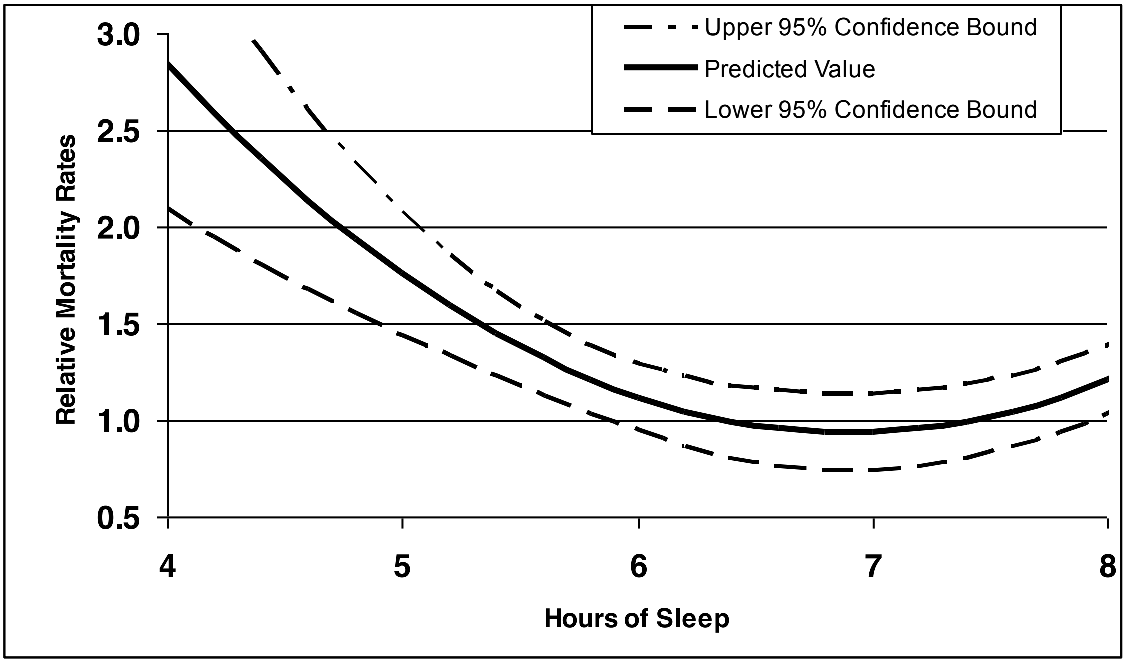

Exhibit 5-4. Sleep mortality function

Although the fitted normal distribution to the hours of sleep is standard statistical modeling (assuming we are correct to treat a response of 6 as meaning from 5.5 to 6.5, etc.), the quadratic regression analysis is highly approximate because it does not take into account how the covariates affect the estimated mortality ratios. However, it should be a good approximation.

The following model was estimated for the distribution of hours of sleep, assuming "6" means between 5.5 and 6.5 hours, and so forth. This model uses the sleep frequency distribution presented in Phase 1 of the study and best-fitting normal distribution.

Normally distributed:
Mean = 6.787198
Standard Deviation = 0.76828

Regression model for mortality hazard ratio, assuming:
Hazard ratio = a + b*exph + c*exphh + error
Exph = expected value of hours of sleep
Exphh = expected value of hours of sleep squared
Error is normally distributed with mean zero

Parameter	Value	Standard Error	P-value
A	11.76028	1.0430	0.0078
B	-3.13766	0.3067	0.0094
C	0.227359	0.0219	0.0092

For example, if the hours of sleep is exactly 7, then exph = 7 and exphh = 49 and so the predicted hazard ratio = 0.937228
If the hours of sleep is the interval from 6.5 to 7.5, then:
Exph = 6.971673
Exphh = 48.68249
Predicted hazard ratio = 0.95392

Exhibit 5-4 shows the shape of this function, along with confidence bounds based on the regression.

Similar to the sleep function discussed above, the change in mortality can then be estimated by calculating the difference between the sleep/mortality function evaluated at the projected hours of sleep per day under the HOS Option and the baseline hours slept per day, shown below:

$$\text{Change Mortality} = (-3.138 \times S^2 + 0.227 \times S + 11.706)$$
$$- (-3.138 \times B^2 + 0.227 \times B + 11.706)$$

where S is the hours of sleep under the HOS Option and B is the hours of sleep under the baseline.

To see more concretely how these functions are used to quantify and monetize the reductions in mortality associated with changes to the HOS rules, it helps to follow through a specific example. The Agency has refined the approach used in the NPRM to better analyze certain implications of the Final Rule. We begin by reviewing the NPRM approach, followed by a detailed description of the refinements employed here. The remainder of this section traces through the effects of the first of the three regulatory alternatives (Option 2) for one group of drivers (the very high intensity group) and one assumption about baseline sleep (low), using the NPRM methodology. The application of the method is the same for all options, intensities, and baseline sleep levels. For example, under Option 2, for the very high intensity group with low sleep, the value of the change in mortality from the equation above is approximately 2.11 percent.

We calculated the effect of a change in mortality rates on life expectancy using information on mortality rates and life expectancy for a cross-section of ages that might be affected by a change in sleep. Actuarial data on a hypothetical population of 100,000 male infants show that more than 98,000 can be expected to survive to 21, the age at which they could become interstate truck drivers.[26] From that point, individuals at each age have a projected life expectancy, and a

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[26] This analysis focuses on males because they currently constitute a large majority of truck drivers.

mortality rate (i.e., chance of dying before reaching their next birthday). More formally, for each age i from 21 to a maximum age (e.g., 110), there is a remaining population P_i, with morality rate M_i, and a life expectancy e_i. P_i can be expressed as $P_{i-1} \times (1 - M_{i-1})$. The remaining population at each successive age is, thus, marginally smaller than at the preceding age due to the small percentage dying each year.

If an additional individual dies at age i, the expected change in life years in the population is equal to the life expectancy for an individual of that age. In other words, if an individual dies at age i, the loss of expected life years equals e_i. For simplicity, we assumed that a mortality change of x percent would apply equally across the population at all ages. Thus, at each age, the number of deaths would rise from $P_i \times M_i$ to $P_i \times (M_i \times [1 + x\%])$, for an increase of $P_i * (M_i \times x\%)$, and the expected life years lost for each age cohort would be $P_i * (M_i \times x\%) * e_i$. Summing across age cohorts gives $\sum_{i=21}^{i=110}[P_i \times (M_i \times x\%) \times e_i]$, or, equivalently, $x\% \times \sum_{i=21}^{i=110}[P_i \times M_i \times e_i]$ as the total years lost out of an initial population of 98,344. Thus, the total years lost for a percentage increase in mortality is proportional to the increase, and is equal to the initial population times the average life years lost for those dying in the baseline. Given the actuarial data for American men, we found that each 1 percent increase in mortality is associated with the loss of an expected 11,365 years of life for an initial population of 98,344. To find the lost life years per individual, we divided the expected loss of 11,365 life years by the initial population of 98,344, obtaining 0.1156 year (that is, almost a month and a half) per 1 percent increase in mortality. Thus, a reduction in mortality of 2.11 percent would be associated with an increased life expectancy of 2.11 × 0.1156, or 0.24 year.

The next step taken in calculating the health benefits of the HOS rule was to monetize the estimated changes in mortality risk. The valuation of increased safety and health—or of reductions in mortality—under each regulatory option can be accomplished using the concept of a VSL. A VSL is used to place a monetary value on incremental mortality risk reduction. VSL is the monetary value of a mortality risk reduction that would prevent one *statistical* (as opposed to an identified) death [Jones-Lee (2004)]. From the VSL, we can calculate a VSLY, which is the annualized value of a VSL throughout an individual's expected remaining years. At the NPRM stage, after calculating the expected mortality improvement, we monetized this improvement by using an estimate for the VSLY. Using DOT's current estimated VSL of $6 million [Szabat (2009)], and assuming a discount rate of 3 percent and an assumption of an average of 37 years of life remaining for drivers (assuming a typical driver is 40 years old), the VSLY is calculated as $270,670. Then, using the estimate of the years of life gained per driver for the different categories of drivers, we estimated the value of years gained by multiplying the calculated VSLY by the years gained per driver per career. For example, for the very high intensity group with a low baseline level of sleep, this resulted in a value of years gained of $66,032 ($270,670 × 0.24 year) per driver per career. We then repeated this calculation for each driver category and the different baseline levels of sleep.

The penultimate step in the calculation of health benefits was to calculate the value of improvement in mortality per year of improved sleep by dividing the total value of years gained by the average length of a driver's career (35 years). This step was taken on the assumption that the full improvement in life expectancy occurs only for drivers who sleep more during their entire careers, and that sleeping more for only a single year or a few years would have a proportionately smaller benefit.[27] For the very high intensity group with a low baseline level of sleep, for example, this calculation yielded a gain per year of $1,887 in terms of reduced mortality.

Finally, we calculated the total value of improvements to mortality by multiplying the per-driver value of improvement in mortality per year by the number of drivers. For example, for the very high intensity group with a low baseline level of sleep, the total value of improvements in mortality was approximately $302 million ($1,887 × 160,000 drivers). We then repeated this calculation for each driver category and the different baseline levels of sleep, and summed them across the categories. The total value for the low baseline sleep group for all intensity categories was $1.43 billion while the total value for the medium baseline sleep group was $672 million. Finally, the total value for the high baseline level of sleep group for all intensity categories was -$88 million indicating that the additional sleep would be detrimental to driver health. This negative value is the result of the U-shaped relationship between average sleep per night and mortality rates mentioned above.

Our revised approach values avoided deaths at the full VSL instead of the average loss of VSLYs for the population. We have presented the NPRM analysis in its entirety before presenting the alternative approach to make the changes completely transparent. The reasons for this refinement in methodology stem from conflicting docket comments submitted by Jane Ferrie and Francesco Cappuccio, co-authors (with several other researchers) of the Whitehall study from which our sleep mortality ratio was developed. In light of their differing views on the applicability of their study to HOS rulemaking, the Agency re-analyzed the study and noted that the time horizon for the study was relatively short – 12 to 17 years, and that the study indicated that individuals who changed their sleep duration in the five years separating Phase 1 and Phase 3 of the study experienced changes in expected mortality. The onset of the effects of sleep improvement were much nearer term than the Agency assumed at the NPRM stage, as will be described below. As a result the Agency re-evaluated its approach to monetizing changes in mortality to use the VSL, rather than changes in expected life years monetized as VSLY, to value changes in mortality.

In addition to presenting cross-sectional results on the differences in mortality over the study period as related to differences in reported sleep at the beginning of the period, the Ferrie study also presented data on the differences in mortality in the second period as related to changes in sleep between the periods. Though these latter results are arguably more relevant to predicting the effect of a rule offering greater opportunities for sleep, FMCSA considered them less useful for the benefits analysis than the cross-section data on differences in sleep. First, there exists a much broader range of studies that studied differences in sleep than changes in sleep, making it easy to place the cross-sectional results into the context of the consensus on the U-shaped sleep/mortality curve. Comparing the results of different studies of the U-shaped sleep/mortality curve gave FMCSA confidence that the results it used from Phase 1 of the Ferrie study fell well within that broad consensus. Second, the cross-sectional results were based on the full sample,

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[27] A driver near the end of his or her career, for example, might gain relatively little, but only because the restriction on work hours would affect him or her for relatively few years. The benefit per year of work, though, is potentially the same as for other drivers.

whereas the data points for changes in sleep necessarily formed a subset of that sample: only about half of the subjects changed their sleep pattern between the phases, and most of those changes were either reductions in sleep or increases to beyond the optimal level (which, arguably, would have been less relevant to the benefits analysis). Finally, the generally close agreement between the cross-sectional and change-in-sleep impacts, and the minor influence of changes in the assumptions about the time span of the effects of changes in sleep on discounted benefits, strongly suggested that the use of the more robust cross-sectional results could be used as a proxy for the effects of changes in sleep.

The change in methodology made for the final rule involves adopting time horizons for the realization of benefits that are more consistent with the Ferrie study and other studies that examine the effects of sleep duration on mortality. It follows the methodology presented above fairly closely, except that instead of looking at average life years gained for the entire affected population, we look more carefully at when mortality impacts are likely to occur and value any early deaths that are prevented at the full VSL. Presenting this change necessitates providing greater detail on a number of factors. First, a more detailed presentation of when benefits occur is necessary. Second, it is necessary to present detail on the age distribution among drivers, and expected mortality rates and how they are expected to change based on changes in sleep.

The main advantage of this approach is that it enables more formal discounting of health benefits that occur in the future and ensures better compliance with OMB guidance on how discounting of benefits should be conducted. Other than the implicit discount rate inherent in the VSLY, and the discounting of both costs and benefits equally over the ten years following promulgation, no discounting of future benefits was conducted for the analysis that accompanied the NPRM. While use of the VSLY rather than the full VSL for valuing improvements in mortality does to some extent discount benefits that occur well into the future, it is neither a comprehensive approach, nor one that allows for the use of explicit discount rates. Furthermore, the VSLY approach would, if discounting were applied, result in the undervaluation of older lives compared to younger lives, which runs counter to most of the economic research on the VSL. The second advantage of this new approach is that it is more consistent with the findings of the Ferrie study, which became apparent from re-assessing those findings in order to respond to comments received on use of that study.

To summarize the new approach, we first generate an age distribution of the long-haul commercial motor vehicle driver population. We then present the mortality rate at each age, and use that mortality rate and the value applied to an avoided death to calculate the value associated with a given change in the mortality rate. We then use a temporal distribution of how those monetized impacts accrue over time and discount that stream of benefits back to the present value. Finally, we feed that series of mortality-related cost figures into our sleep-mortality function to determine the value associated with changes in mortality if average sleep duration changes.

Ideally, this calculation would be carried out for all ages for a weighted distribution of truck drivers for whom mortality rates are available. Unfortunately, the Agency is unaware of any data source that would provide mortality rates specifically for truck drivers. We therefore start with mortality rates for the general U.S. population, adjusted to account for higher mortality among lower educated and blue collar workers, combined with a weighted distribution of truck driver age. We present our age distribution, which is based on the Census Bureau's American Community Survey (ACS), in Exhibit 5-5 below. Our mortality table for the general U.S. population can be found at http://www.ssa.gov/oact/STATS/table4c6.html. We do not reproduce it here because of its size. The ACS was used as a source of driver ages in an ATA sponsored 2005 report on the driver shortage conducted by Global Insight.[28] We use 2010 data from the ACS to develop our driver age distribution.

Exhibit 5-5. Age Distribution from ACS

Age Cohort	Number in Cohort	Percent
21-29	4,989	11%
30-39	7,682	18%
40-49	10,893	25%
50-59	11,461	26%
60-69	6,569	15%
70+	1,988	5%
Total	43,582	100%

The basic approach uses this truck driver age distribution and applies adjusted mortality rates to that distribution that are equivalent to the mortality rates in the general U.S. population of the same age distribution plus a 25 percent adjustment factor. The Agency deems this adjustment factor reasonable for several reasons. First, available truck driver health statistics indicate that truck drivers are less healthy than the general U.S. population, which is ample reason to believe that they would suffer higher mortality rates than the general population. Many of the health conditions that occur at higher rates among truck drivers, such as heart disease, high blood pressure, diabetes, and obesity, are associated with higher rates of mortality. Furthermore, studies indicate that individuals with a high school education have double the mortality rates of those with greater educational attainment.[29] Since truck drivers tend to have lower educational attainment than the national average, one would expect their mortality to be higher, on average, than the general population. To produce the most precise calculation for this adjustment, we use a detailed breakdown from the previous Census to estimate the difference in mortality: [(death rate for < HS) x (driver% with < HS) + (death rate for HS) x (driver% with HS) + (death rate for > HS) x (driver% with > HS)]/ (death rate for all). Exhibit 5-6 below shows the calculations – the Percentage column is multiplied by the Age Adjusted Mortality column to get the weighted mortality adjustment for each educational attainment category. The figures in that column are summed to get the weighted mortality for drivers of all education levels. Then that figure is divided by the mortality rate for the general U.S. population to get the final adjustment factor of 1.25.

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[28] Global Insight. (2005). *The U.S. Truck Driver Shortage: Analysis and Forecasts.* American Trucking Associations. Available online at: http://www.cdlschool.com/_pdf/ATADriverShortageStudy05.pdf.

[29] Hoyert, Donna L. et al. (2001). "Deaths: Final Data for 1999." *National Vital Statistics Reports* 49(8):Table 23

Exhibit 5-6. Mortality Rate Adjustment Calculations

Education level of drivers	Percentage	Age Adjusted Mortality	Weighted
< 12 Years	21.8%	763.7	166.5
12 Years	58.3%	636.7	371.2
13+ Years	19.8%	264.2	52.3
Weighted mortality rate for drivers:			590.6
Mortality rate for general population:			472
Adjustment factor based on educational attainment differential:			1.25

This figure corroborates actuarial tables for blue collar workers – these tables indicated that blue collar workers have rates of mortality that are roughly 25 percent higher than for "mixed" collar workers.[30,31] We account for the higher expected mortality of truck drivers by applying this factor to our mortality tables. For example, instead of a 0.0097 chance of dying within the year, a 55 year old truck driver would have a roughly a 1.2 percent (0.0097 x 1.25) chance of dying within the year.

The final step in the calculation is determining how long this sleep improvement must continue before it starts generating health benefits, and how sustained those health benefits might be. The multi-phase Ferrie study provides insight regarding these questions. There were about 5 years between Phase 1 and Phase 3 of the Ferrie study. One of the findings presented in the Phase 3 results is that individuals who were getting insufficient sleep at Phase 1, but increased the amount of sleep they were getting from Phase 1 to Phase 3, saw large to dramatic mortality improvements (and similarly, reductions in sleep between phases led to large increases in mortality). Put another way, the Phase 3 study found that individuals who increased their average sleep duration relative to their sleep duration during the Phase 1 stage experienced reductions in mortality that were seen within the 12 years remaining in the study. In fact, the changes in mortality seen to result from these changes in sleep between phases appear to be comparable, or even stronger, than would be predicted using the sleep/mortality functions FMCSA derived from the Ferrie Phase 1 results, and used for the RIA.

Given that the data collection timespan between Phase 1 and Phase 3 was about 5 years, it appears that only a few years of improved sleep provide mortality reduction benefits. Phase 3 of the Ferrie study tracked the cohort for 12-17 years (depending on whether the starting point is Phase 1 or Phase 3), so we have a 12-17 year distribution of mortality improvements that can be used to determine how benefits are distributed over time. For the purposes of the HOS analysis, we use a 17-year time horizon over which mortality improvements accrue for a driver of a given age. That is, in each year, 1/17th of the total mortality reduction benefits would accrue to a driver who is given more opportunity for sleep. Thus, if a driver of a certain age gets more sleep, we can look at how that driver's mortality risk evolves over a 17-year timespan, place a value on the reduction in mortality risk, multiply this value by the number of drivers in that age cohort, and

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[30] Society of Actuaries. The RP-2000 Mortality Tables. 2000. Available online at http://www.soa.org/files/pdf/rp00_mortalitytables.pdf

[31] American Academy of Actuaries News Release. "Blue Collar Death Rates Higher, Actuarial Study Shows." 2000.

discount back to the present value when benefits occur in the future. This produces a stream of benefits over time as the driver ages, and mortality rates and reductions in mortality change.

Next, we turn to a discussion of the value that should be placed on mortality reductions. One approach would be to look at expected remaining life-years at each age, and calculate the cost of early mortality for a person of that age by summing the stream of statistical life-years that are lost, appropriately discounted. However, this approach values older people less than younger people, given that older individuals have fewer remaining statistical life-years. Because the FMCSA believes it is proper to value human life equally, regardless of age, the analysis monetized each avoided death at the full VSL.[32]

Stated more formally, to find the present discounted value of reducing truck driver mortality by 1%, for a total population of 1.6 million, 95 percent male, divided into 6 cohorts of 25, 35, 45, 55, 65, and 75, we evaluate the following expression:

$$\sum_{a=c}^{c=17}[(L_a - L_{a+1})/L_c]*0.01/17*VSL/(1+r)^{(a-c)} \quad \sum_{c=25}^{75} P*f_c$$

where:

L is the number of living individuals from an initial cohort of 100,000 who are still alive, calculated as a weighted average of American men still alive by age, adjusted to increase mortality rates at each age by a factor of 1.25, and American women still alive by age;

L_a is the number alive at age a (and L_{a+1} is the number still alive a year later);

L_c is the number alive in a cohort that was c years old when the rule goes into effect;

0.01 converts the death rates to one percent of annual death rates;

17 is the number of years over which the mortality effects are assumed to be spread (i.e., a one-year sleep change is assumed to have 1/17th of the effect of 17 years of sleep change), in each of the next 17 years;

VSL is the value of a statistical life, taken to be $6 million;

r is the annual discount rate, evaluated at r=3% and 7%.

P is the population of drivers (taken to be 1,600,000); and

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[32] The current consensus of economic research on the VSL is that older individuals place the same value on avoiding mortality risk as younger individuals, and therefore their lives have equal value regardless of their relatively advanced age. Indeed, it is the current policy of several Federal agencies to value mortality effects using the full VSL, and recent expert panels have recommended not treating older lives with a discount in comparison to younger lives. Using the full VSL ensures that reductions in mortality will have equal value regardless of the age of the life saved.

f_c is the fraction that falls into age cohort c (estimated to be 11% , 18%, 25%, 26%, 15%, for drivers around 25, 35, 45, 55, 65, and 75 respectively, based on age categories from 21 through 29, 30 through 39, etc.).

Exhibit 5-7 shows, for one of 6 age cohorts, how we implement this approach. The first column shows the ages for a particular cohort of drivers, starting at 55 years in the year the rule takes effect. The next column shows the percentage of drivers of this age who are expected to die in each coming year, for typical American truck drivers.[33] The next column shows the value of preventing 1 percent of those deaths, if each averted death (as stated above) is assumed to be worth $6 million in the year that it takes place. (Notice that the values are rising, because expected deaths in the baseline rise as individuals age.) The next column presents these values discounted back to the first year of the rule (when our cohort is about 55) at a rate of 7 percent per year. (Note that these discounted values do not change much as time goes on, because the discount rate and the rate of increase in deaths largely cancel each other out.) We then average the discounted benefits for each future year for a period of 17 years (the length of the Ferrie study, starting at Phase 1), under the assumption that the benefits of any particular year of improved sleep might phase in linearly over that timespan.

To get the final benefit, we multiply the expected mortality improvement for our entire driver population of all intensity levels by the value of a 1 percent improvement in mortality calculated as shown. As one example, if the mortality improvement is 0.433 percent (the value calculated for Option 3 under the medium sleep assumption), the value per 1 percent improvement would be multiplied by 0.433 to yield the annual value of the health for one driver in this cohort. We then multiply the per-driver value by the number of drivers in the cohort. The 50-60 year old cohort make up 26 percent of the total driver population of 1.6 million, so we multiply the per-driver value by 26 percent of 1.6 million, or 416,000 drivers. We then multiply the expected discounted per-driver benefit by the number of drivers (in this case $237.49 x 416,000). In the example, multiplying the per-driver value of $237.49 by 416,000 drivers in the cohort gives total present value benefits of $98.8 million for this age cohort. We repeated these calculations for each age cohort, and summed the figures for all cohorts to get a final estimated benefit for the entire population.

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[33] The values in the table represent a weighted average of U.S. men and women, adjusted for our estimate of the increased mortality of male truck drivers compared to males in the general population. Only a small fraction of drivers are women; they make up 5 percent or less of the CMV driver population [this is not a complete sentence]. Adjusting the female mortality figures would therefore add significant complexity to the analysis but have virtually no effect on the final figures (i.e., the difference would be well within the rounding error).

Exhibit 5-7. Mortality Reduction Benefits for 55 Year-Old Age Cohort

Age by Year	Fraction dying	Value of 1% Mortality Reduction	Discounted
55	0.0097	$580.86	$580.86
56	0.0103	$616.72	$576.37
57	0.0109	$654.84	$571.96
58	0.0116	$695.18	$567.47
59	0.0123	$738.38	$563.31
60	0.0131	$785.75	$560.23
61	0.0139	$836.69	$557.52
62	0.0148	$889.48	$553.92
63	0.0157	$943.44	$549.09
64	0.0167	$999.85	$543.85
65	0.0177	$1,061.67	$539.70
66	0.0188	$1,129.05	$536.40
67	0.0200	$1,200.06	$532.84
68	0.0212	$1,274.37	$528.82
69	0.0225	$1,352.04	$524.34
70	0.0239	$1,436.74	$520.74
71	0.0254	$1,525.44	$516.72
Average Value per Year over 17 Years:			$548.48
Value per Driver for 0.433 percent Improvement:			$237.49
Total Value for 416,000 Drivers:			$98,796,422

Changing the assumption about the length of time over which the benefits are spread would affect these results, but not by very much. Because the improvement in sleep affects mortality rates, and because mortality rates rise over time (at about 7 percent per year) for each cohort, delaying the start of the benefits or spreading them out over time tends to cancel out the effects of greater discounting. At a 7 percent discount rate, discounted benefits stay roughly constant as the assumed timespan is increased except for very extreme spans; at 3 percent, the discounted benefits actually increase over a wide range of timespans. Exhibit 5-8 below presents the benefits associated with various other time horizons relative to the 17 year horizon used for the analysis.

Exhibit 5-8. Benefits Relative to Benefits using a 17 Year Timespan

Timespan	7% Discount Rate	3% Discount Rate
1	115%	85%
5	112%	90%
12	106%	97%
15	103%	99%
17	100%	100%
35	74%	95%

5.3. UNQUANTIFIED HEALTH BENEFITS

In addition to the quantified and monetized benefits discussed above, there may be other health benefits that shorter workdays and weeks could produce. Research indicates that the metabolic and endocrine disruptions associated with short sleep time and long work hours are significantly related to obesity [Van Cauter & Knutson (2008) and Di Milia & Mummery (2009)]. Obesity is in turn associated with higher incidences of diabetes, cardiovascular diseases, hypertension, and obstructive sleep apnea [Mokdad, *et al.* (2001)]. Each of these medical conditions imposes costs on drivers who suffer from them and affects the quality of their lives. Sedentary work alone is also associated with obesity and mortality impacts [Katzmarzyk, *et al.* (2009)].

Research on the health and health costs for CMV drivers found that drivers are both heavier for their height and less healthy than the adult male population of workers. Drivers are far more likely than the adult worker population as a whole to be obese. Exhibit 5-5 presents the distribution of drivers by weight category and the incidence of health conditions for each weight group from a study of 2,950 CMV drivers [Martin, *et al.* (2009)]. (The national statistics for adult males include men older than 70, who may have higher incidences of some conditions than the younger working population.)

We have not attempted to quantify every type of health benefit that may accrue to drivers who have more time off. First, FMCSA does not have dose-response curves that it can use to associate sleep time to mitigation or exacerbation of the various health impacts other than sleep loss itself. Second, FMCSA has no basis for estimating the extent to which drivers who have an extra hour a day off duty or extra hours per week would use that time to exercise. Third, many of the health impacts are linked to obesity; given the difficulty most people have in losing weight, it would be unjustifiably optimistic to attempt to estimate the degree of potential weight loss.

Exhibit 5-9. Driver Health Conditions by Weight Category

N = 2,950	Percent in Weight Category	Presence of at Least One Health Risk Factor	Hypertension	Diabetes	High Cholesterol
Normal Weight	13%	26%	21%	5%	11%
Overweight	30%	39%	31%	10%	17%
Obese	55%	59%	51%	21%	26%
Overall	5%	48%	41%	16%	21%
National Adult Male			31.80%	10.9% (7.4% diagnosed)	15.60%

The health impacts that flow from inadequate sleep and long stretches of sedentary work are, however, significant: they cause serious health conditions that may shorten a driver's life and increase healthcare costs. In addition, some studies have linked obesity to increased crash risks, including a recent analysis of the Hanowski, et al (2007) data, which found that obese CMV drivers were between 1.22 and 1.69 times as likely to drive while fatigued, 1.37 times more likely to be involved in an SCE, and at 1.99 times greater risk of being above the fatigue threshold as measured by eye closure when driving [Wiegand, et al (2009)].

6. Results

This chapter presents the results of the economic analysis of the HOS rule changes. First, we summarize the costs of Options 2 through 4. As discussed previously, Options 2 through 4 require at least one break during long duty days (none is currently required), and limit the use of the 34-hour restart provision to once every 168 hours with at least 2 nights off duty. Options 2 through 4 differ only in driving time allowed between 10-hour breaks. Option 2 limits allowable daily driving to 10 hours, the driving limit that existed prior to the 2003 rule. Option 3 retains the 11 hours of driving allowed under the current rule. Option 4 allows only 9 hours of driving, or 1 hour less than Option 2.

The costs of Options 2 through 4 consist of annual operational costs that result from lost productivity and one-time rule training and reprogramming costs which drivers and carriers incur as a result of the rule changes. These two cost components are summed to obtain the total costs for the options. Next, the benefits of the Options 2 through 4 are presented. The benefits consist of safety benefits from the reduction in fatigue-related crashes and health benefits from drivers working long hours potentially getting more sleep and reducing their mortality risk. These benefit categories are summed to obtain the total benefits of the options. The chapter then presents the net benefits of Options 2 through 4 by subtracting total costs from the total benefits. Next, we briefly discuss the limitations of our analysis. Next, the chapter analyzes the sensitivity of the net benefit estimates for the options to changes in the VSL. The chapter then presents a summary of the results for the options. We next discuss the mode shift implications of the options and the implications of the options on the number of drivers. We then conclude the chapter with a discussion of the safety impacts of new drivers and mode shifts.

In brief, this chapter shows annualized costs of about $1 billion for Option 2, about $470 million for Option 3, and more than $2.29 billion for Option 4. These costs can be compared to annual safety and health benefits estimated to range from $270 million to more than $1.64 billion for Option 2 ($260 million to $1.92 billion at 3 percent discounting), from $220 million to $1.02 billion for Option 3 ($250 million to $1.24 billion at 3 percent discounting), and from $240 million to $2.68 billion for Option 4 ($110 million to $3.06 billion at 3 percent discounting), under different baseline assumptions. Net benefits, as a result, are likely to be positive, but could range from a negative $730 million per year to more than a positive $630 million per year for Option 2 (-$750 million to $920 million at 3 percent discounting), from a negative $250 million per year to more than a positive $550 million per year for Option 3 (-$220 million to $770 million at 3 percent discounting), and from a negative $2.05 billion to more than a positive $390 million for Option 4 (-$2.18 billion to $780 million at 3 percent discounting). The wide ranges in estimates of benefits and net benefits are a consequence of the difficulty of measuring fatigue and fatigue reductions, which are complex and often subjective concepts, in an industry with diverse participants and diverse operational patterns. Still, it seems clear that the benefits for Options 2 through 4 could easily be substantial, and are on the same scale as the costs for these options. The costs, for their part, are large in absolute terms but minor when compared to the size of the industry: the costs of Option 2 (about $1 billion per year) is only half of 1 percent of revenues, the costs for Option 3 (about $470 million per year) is only one quarter of 1 percent of revenues, and the costs for Option 4 (about $2.29 billion per year) is only 1 percent of revenues in the for-hire LH segment of the industry. These total annual costs are an even smaller fraction of revenues of the LH segment as a whole.

Compared to the other options that were analyzed, Option 4 would have roughly twice the costs of Option 2 and more than four times the cost of Option 3. In keeping with their relative stringencies, Option 3 has lower, and Option 4 has higher, projected benefits than Option 2. Option 3's calculated net benefits appear likely to be somewhat higher than the net benefits of Option 2 under some assumptions about baseline conditions, but lower under other assumptions. Option 4's substantially larger costs, on the other hand, did not appear to be justified by its generally higher range of benefits. In addition to the analyses presented in this chapter, the Agency has conducted a series of analyses to evaluate the costs and benefits of the individual components of this rule. These ancillary analyses can be found in Appendix C of this regulatory evaluation, and include examining the costs and benefits of each rule component for varying levels of baseline fatigue involvement and discount rates.

6.1. COSTS

The costs of Options 2 through 4 consist of operational changes, which accrue annually from losses in productivity when drivers adjust to the new HOS rule provisions, and from training and reprogramming costs, which drivers and carriers incur one time to adjust to the new HOS rule provisions. These cost categories are then summed to estimate the total costs of the options.

6.1.1. Operational Costs

The methodology for estimating the costs of operational changes that result from the new HOS rule provisions was described in Chapter 3. As described earlier, the new HOS rule provisions affect drivers differently, based on the intensity of their work schedule. Costs were thus estimated separately for different categories of drivers. As discussed in Chapter 3, costs of operational changes result from three effects of the new HOS rule: reduction of daily work hours, reduction of weekly work hours, and reduction in work time due to the restart provision. We have not estimated the effects of several less important rule provisions, for reasons discussed in Section 6.5. Exhibits 6-1 through 6-3 present the results of our estimation of the costs of each of these three effects for each category of drivers for Options 2 through 4. The costs of these effects are then totaled for each category of drivers, and then summed across all drivers to obtain the total cost of operational changes for Option 2 through 4. As shown in Exhibits 6-1 through 6-3, the total annual cost is \$960 million for Option 2, \$430 million for Option 3, and \$2.25 billion for Option 4 (measured, as are all of the monetary values in this RIA, in 2008\$).

Exhibit 6-1. Costs of Operational Changes by Allowed Daily Hours of Driving for Option 2 (Millions 2008$)

Driver Category	30-Minute Break Provision	Reduction of Daily Driving Hours	Reduction Due to Restart Provisions	Total
Moderate	$0	$160	$0	$160
High	$10	$150	$0	$160
Very High	$30	$190	$30	$250
Extreme	$60	$130	$200	$390
Total	$90	$630	$230	$960

Note: Totals do not add due to rounding.

Exhibit 6-2. Costs of Operational Changes by Provision for Option 3 (Millions 2008$)

Driver Category	30-Minute Break Provision	Reduction of Daily Driving Hours	Reduction Due to Restart Provisions	Total
Moderate	$0	$0	$0	$0
High	$10	$0	$0	$10
Very High	$30	$0	$30	$60
Extreme	$60	$0	$300	$360
Total	$90	$0	$330	$430

Note: Totals do not add due to rounding.

Exhibit 6-3. Costs of Operational Changes by Provision for Option 4 (Millions 2008$)

Driver Category	30-Minute Break Provision*	Reduction of Daily Driving Hours	Reduction Due to Restart Provisions	Total
Moderate		$710	$0	$710
High		$550	$0	$550
Very High		$510	$30	$540
Extreme		$350	$100	$450
Total		$2,120	$130	$2,250

Note: Totals do not add due to rounding.
* The costs associated with the limit on daily driving hours are combined with the much greater costs of reduced daily driving hours for this option.

6.1.2. Training and Reprogramming Costs

Drivers and carriers also incur costs due to the need for drivers to be trained in the new rule provisions and for carriers to reprogram their equipment. Based on the judgment of FMCSA's experts on enforcement training, drivers would need a total of 2 hours of training to learn the new HOS rule provisions. To estimate the cost of this effort, we used U.S. Bureau of Labor Statistics truck driver wage data, which showed 3.34 percent annual hourly wage increases for the period from 1998 through 2007.[34] We applied this growth rate three times to the 2007 Bureau of Labor Statistics weighted average hourly truck driver wage rate of $16.58 to arrive at a 2010 hourly rate of $18.29. We then multiplied the 2010 wage rate by 1.31 to obtain a loaded average hourly rate of $23.96 (wages plus fringe benefits). The 2-hour training course thus resulted in a cost of $47.92 per driver.

Carriers would incur additional one-time costs for software reprogramming and other transition costs. These costs were estimated using information obtained from the HOS listening sessions conducted in various locations in early 2010. Based on information from these sessions, we assumed that the total one-time training, reprogramming, and other transition costs were about $200 per driver (including the approximately $48 per driver cost discussed above). To obtain an industry-wide cost, we multiplied this per-driver cost of $200 by the total number of drivers (1,600,000) to obtain a total one-time cost to the industry of approximately $320 million. We amortized this cost throughout 10 years using a 7-percent discount rate to obtain an annualized cost of roughly $40 million.

6.1.3. Total Costs

The next step was to sum the annual and one-time costs to obtain a total cost of the new HOS rule for Options 2 through 4. As shown below in Exhibit 6-4, summing the different cost components resulted in a total cost of $1.00 billion for Option 2, $470 million for Option 3, and $2.29 billion for Option 4. Though these costs are estimated using impacts on industry productivity, they would most likely be passed along as increases in freight transportation rates, and then ultimately to consumers in increased prices for the goods that are transported by truck. As mentioned in Chapter 3, however, these price increases would be relatively small even for a rule imposing substantial total annual costs: a total annual increase in freight costs of $1.0 billion, $470 million, or $2.29 billion would be on the order of $9, $4, and $20 per household per year, respectively.

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[34] http://data.bls.gov:8080/oep/servlet/oep.noeted.servlet.ActionServlet

Exhibit 6-4. Total Costs for All Options (Millions 2008$)

Cost Category	Option 2	Option 3	Option 4
30-minute Break Provision	$90	$90	*
Reduction of Daily Driving Hours	$630	$0	$2,120
Reduction Due to Restart Provisions	$230	$330	$130
Training and Reprogramming Cost	$40	$40	$40
Total Costs	**$1,000**	**$470**	**$2,290**

* The costs associated with the limit on daily driving hours are combined with the much greater costs of reduced daily driving hours for this option.

6.2. BENEFITS

Next, we estimated the total benefits of Options 2 through 4 by summing the two categories of benefits arising from the new rule: safety benefits and health benefits.

6.2.1. Safety Benefits

As described in Chapter 4, safety benefits arise from the reduction in the probability of fatigue-related crashes by LH drivers. This crash reduction is thought to arise from two effects: reduced acute TOT effects from restrictions in daily driving time, and reduced cumulative TOT effects from reductions in weekly work time. The monetary value of each of these effects was estimated under three different assumptions of the baseline level of fatigue involvements in crashes: 7 percent, 13 percent, and 18 percent. The total benefits resulting from improvements in the safety of LH drivers for Options 2 through 4 are shown in Exhibits 6-5 though 6-7.

Exhibit 6-5. Safety Benefits (Dollars) for Option 2 (Millions 2008$)

Assumed Percent of Crashes Due to Fatigue	Benefits Due to Reduced Daily Time on Task Effect[a]	Benefits Due to Reduced Weekly Time on Task Effect[b]	Total Benefits Due to Reduced Crashes
7 percent	$110	$210	$320
13 percent	$210	$390	$600
18 percent	$290	$540	$830

a. Acute fatigue from long hours in a day

b. Cumulative fatigue from long hours over many days

Exhibit 6-6. Safety Benefits (Dollars) for Option 3 (Millions 2008$)

Assumed Percent of Crashes Due to Fatigue	Benefits Due to Reduced Daily Time on Task Effect[a]	Benefits Due to Reduced Weekly Time on Task Effect[b]	Total Benefits Due to Reduced Crashes
7 percent	$10	$150	$150
13 percent	$10	$270	$280
18 percent	$10	$380	$390

a. Acute fatigue from long hours in a day

b. Cumulative fatigue from long hours over many days

Note: Totals do not add due to rounding.

Exhibit 6-7. Safety Benefits (Dollars) for Option 4 (Millions 2008$)

Assumed Percent of Crashes Due to Fatigue	Benefits Due to Reduced Daily Time on Task Effect[a]	Benefits Due to Reduced Weekly Time on Task Effect[b]	Total Benefits Due to Reduced Crashes
7 percent	$290	$320	$610
13 percent	$550	$590	$1,130
18 percent	$760	$810	$1,570

a. Acute fatigue from long hours in a day

b. Cumulative fatigue from long hours over many days

Note: Totals do not add due to rounding.

In addition to estimating the monetary value of the improvements in safety, we also estimated the lives saved due to the safety improvements. To estimate lives saved, we assumed that the new rule would have the same relative effect on fatalities as on all crash damages caused by heavy trucks. The resulting estimates of the total lives saved for Options 2 through 4 are shown in Exhibits 6-8 though 6-10.

Exhibit 6-8. Safety Benefits (Lives Saved) for Option 2

Assumed Percent of Crashes Due to Fatigue	Lives Saved Due to Reduced Daily Time on Task Effect[a]	Lives Saved Due to Reduced Weekly Time on Task Effect[b]	Total Lives Saved Due to Reduced Crashes
7 percent	8	14	21
13 percent	14	26	40
18 percent	19	36	55

a. Acute fatigue from long hours in a day
b. Cumulative fatigue from long hours over many days
Note: Totals do not add due to rounding.

Exhibit 6-9. Safety Benefits (Lives Saved) for Option 3

Assumed Percent of Crashes Due to Fatigue	Lives Saved Due to Reduced Daily Time on Task Effect[a]	Lives Saved Due to Reduced Weekly Time on Task Effect[b]	Total Lives Saved Due to Reduced Crashes
7 percent	0	10	10
13 percent	1	18	19
18 percent	1	25	26

a. Acute fatigue from long hours in a day
b. Cumulative fatigue from long hours over many days
Note: Totals do not add due to rounding.

Exhibit 6-10. Safety Benefits (Lives Saved) for Option 4

Assumed Percent of Crashes Due to Fatigue	Lives Saved Due to Reduced Daily Time on Task Effect[a]	Lives Saved Due to Reduced Weekly Time on Task Effect[b]	Total Lives Saved Due to Reduced Crashes
7 percent	20	21	41
13 percent	36	39	75
18 percent	50	54	104

a. Acute fatigue from long hours in a day
b. Cumulative fatigue from long hours over many days

6.2.2. Health Benefits

Next, we estimated the total benefits due to improvements in driver health, as described in Chapter 5. The health benefits of Options 2 through 4 were estimated for three different levels of baseline sleep by drivers at 7 and 3 percent discounting of future health benefits (shown in Exhibit 6-11). For the assumption of a high level of baseline sleep for Options 2 and 4, it is interesting to note that the benefits are negative, indicating that it is not beneficial for individuals to get additional sleep if they are already getting adequate sleep. It is unlikely that drivers in the extreme and very high groups, who are principally affected by the rule changes, would be able to obtain to the amount of sleep projected for the high sleep category. Even drivers working 50 to 60 hours a week sleep less than the projected high sleep of 6.59 and 7 hours on many workdays. For any of these drivers who are driving at night, the estimated baseline sleep is likely to be substantially less across all categories.

Exhibit 6-11. Annual Health Benefits for Options 2 through 4 (Millions 2008$)

Assumed Baseline Amount of Nightly Sleep	Total Benefits Due to Increased Sleep					
	7 Percent Discounting			3 Percent Discounting		
	Option 2	Option 3	Option 4	Option 2	Option 3	Option 4
Benefits with Low Sleep	$810	$630	$1,110	$1,090	$850	$1,490
Benefits with Medium Sleep	$380	$350	$370	$510	$470	$500
Benefits with High Sleep	-$50	$70	-$370	-$70	$90	-$500

6.2.3. Total Benefits

The next step was to sum the safety and health benefits to obtain the total benefits of the new HOS rule. Exhibit 6-12 through 6-14 present the results of summing the categories of benefits under different assumptions for the baseline fatigue level and the baseline level of nightly sleep by drivers for Options 2 through 4.

Exhibit 6-12. Total Benefits for Option 2 (Millions 2008$)

Assumed Baseline Percent of Crashes Due to Fatigue	Assumed Baseline Amount of Nightly Sleep					
	7 Percent Discounting			3 Percent Discounting		
	Low Sleep	Medium Sleep	High Sleep	Low Sleep	Medium Sleep	High Sleep
7 percent	$1,130	$700	$270	$1,410	$830	$260
13 percent	$1,410	$980	$550	$1,690	$1,110	$530
18 percent	$1,640	$1,210	$780	$1,920	$1,340	$760

its for Option 3 (Millions 2008$)

Assumed Baseline Percent of Crashes Due to Fatigue	Assumed Baseline Amount of Nightly Sleep					
	7 Percent Discounting			3 Percent Discounting		
	Low Sleep	Medium Sleep	High Sleep	Low Sleep	Medium Sleep	High Sleep
7 percent	$780	$500	$220	$1,000	$620	$250
13 percent	$910	$630	$350	$1,130	$750	$380
18 percent	$1,020	$740	$460	$1,240	$860	$480

Exhibit 6-14. Total Benefits for Option 4 (Millions 2008$)

Assumed Baseline Percent of Crashes Due to Fatigue	Assumed Baseline Amount of Nightly Sleep					
	7 Percent Discounting			3 Percent Discounting		
	Low Sleep	Medium Sleep	High Sleep	Low Sleep	Medium Sleep	High Sleep
7 percent	$1,720	$980	$240	$2,100	$1,110	$110
13 percent	$2,240	$1,500	$770	$2,630	$1,630	$630
18 percent	$2,680	$1,940	$1,200	$3,060	$2,070	$1,070

6.3. NET BENEFITS

Next, we calculated the net benefits of Options 2 through 4 by subtracting the total estimated costs from the total estimated benefits for these options. The resulting net benefit estimates for Options 2 through 4 are shown in Exhibits 6-15 through 6-17 for the different assumed baseline levels of fatigue involvement in crashes and sleep. The net benefits of Option 2 are negative for all three baseline fatigue levels when a high baseline level of sleep for drivers is assumed, and are negative for the 7 percent baseline fatigue level when a medium baseline level of sleep for drivers is assumed. The net benefits of Option 3 are negative for the 7 percent and 13 percent baseline fatigue levels when a high baseline level of sleep for drivers is assumed. The net benefits for Option 4 are negative for all three baseline fatigue levels when a high baseline level of sleep for drivers is assumed, and are negative for all three baseline fatigue levels when a medium baseline level of sleep is assumed. For all three options, the net benefits are positive for all three baseline fatigue levels using the assumption of a low level of baseline sleep for drivers.

Exhibit 6-15. Net Benefits for Option 2 (Millions 2008$)

Assumed Percent of Crashes Due to Fatigue	Assumed Amount of Nightly Sleep					
	7 Percent Discounting			3 Percent Discounting		
	Low Sleep	Medium Sleep	High Sleep	Low Sleep	Medium Sleep	High Sleep
7 percent	$130	-$300	-$730	$410	-$170	-$750
13 percent	$400	-$20	-$450	$690	$110	-$470
18 percent	$630	$210	-$220	$920	$340	-$240

Exhibit 6-16. Net Benefits for Option 3 (Millions 2008$)

Assumed Percent of Crashes Due to Fatigue	Assumed Amount of Nightly Sleep					
	7 Percent Discounting			3 Percent Discounting		
	Low Sleep	Medium Sleep	High Sleep	Low Sleep	Medium Sleep	High Sleep
7 percent	$310	$30	-$250	$530	$150	-$220
13 percent	$440	$160	-$120	$660	$280	-$90
18 percent	$550	$270	-$10	$770	$390	$20

Exhibit 6-17. Net Benefits for Option 4 (Millions 2008$)

Assumed Percent of Crashes Due to Fatigue	Assumed Amount of Nightly Sleep					
	7 Percent Discounting			3 Percent Discounting		
	Low Sleep	Medium Sleep	High Sleep	Low Sleep	Medium Sleep	High Sleep
7 percent	-$570	-$1,310	-$2,050	-$180	-$1,180	-$2,180
13 percent	-$50	-$790	-$1,520	$340	-$660	-$1,650
18 percent	$390	-$350	-$1,090	$780	-$220	-$1,220

6.4. LIMITATIONS OF THE ANALYSIS

This analysis was, of necessity, limited in scope to calculations of what FMCSA judged to be the most important effects of the most important provisions of the rule changes under consideration. We assumed the 30-minute break provision to provide benefits only by reducing cumulative on-duty hours and limiting the chances for long driving days; no additional benefits are counted for the refreshing or "resetting" effect breaks are often thought to have on drivers who have grown fatigued during the course of a long, continuous drive. Counting that additional effect (which was found to cut total risk roughly in half after a break of half an hour), at least temporarily, would undoubtedly add further to the benefits as calculated in this analysis.

As discussed in Sections 4.2 and 4.3, data limitations and the complexity of fatigue processes create significant uncertainty about the effects of long driving hours on crash risks. After considering many studies and possible approaches, the analysis uses a TOT function based on the increase in the percentage of fatigue-related crashes as driving hours increase. This approach has the weakness that the increasing percentage could be due to falling risks of non-fatigue-related crashes, but as discussed in Section 4.3 that weakness is likely to be of theoretical concern only. A more serious question arises from the fact that the determination of fatigue involvement is somewhat subjective, and could be influenced by knowledge of drivers' schedules or the time of day on the part of the person coding the factors related to a crash. The TOT function used in the analysis is, nonetheless, quite consistent with a recent study by Blanco, *et al.* (2011). The TOT function found by the Blanco study is very moderate in magnitude compared to those found by many other TOT studies, and FMCSA considers it to be unlikely to be overstated.

We were unable to account for all of the benefits of the 2-night restriction of the restart provision. The additional costs of this requirement have been included, along with health and safety benefits of the reduction in work hours. The main point of the provision, though, is to address the extra need for rest for drivers on a night schedule. Those circadian-related benefits could not be incorporated at the time this analysis was conducted.

The magnitude of the impact of the 2-night restart provision on productivity was also uncertain, due to uncertainty about the distribution of start and end times of restart breaks, and how those times correlate with the intensity of the drivers' schedules. In the analysis of costs and benefits, we use a weighted average impact of 0.5 hour per week per driver for the very high and extreme intensity drivers. That average, as described in Appendix E, is a combination of 0.27 hour for drivers whose breaks are spread across 3 calendar days and 0.89 hour for those whose breaks span only 2 days. Because the very high and extreme intensity drivers could be over-represented among those with 2-day breaks, the true average for driver in the more intense categories could be closer to the upper end of the range from 0.27 to 0.89. There could also be other reasons for the productivity impacts of the 2-night restart provision to be higher, as well.

To assess the possible impacts of higher productivity impacts on costs and benefits, FMCSA conducted several sensitivity analyses using different changes in hours lost to the 2-night restart provision. First, we increased the loss of on-duty time for the extreme drivers to 0.89 hour per week, reflecting their greater likelihood to compress their restart breaks into only 2 calendar days (i.e., we used the value of 0.89 hour per week appropriate to 2-calendar-day restarts only, rounded up to the nearest tenth of an hour). In this sensitivity run, the loss for the very high intensity drivers was left at 0.50 hour per week. The results showed almost no effect on costs or net benefits: costs rose by between $10 million and $20 million for all options, net benefits rose by $10 million or less in the medium-sleep case, and net benefits rose by $10 million to $20 million in the low sleep case (which is probably the most realistic for the drivers affected by the 2-night restart provision). In other words, this change in the assumptions about the productivity impact of the 2-night restart provision would raise the costs by less than 4 percent of estimated cost of the Final Rule, and would raise benefits by somewhat more in absolute terms, leading to a very minor increase in net benefits. The sensitivity analysis also showed that changes in estimated productivity impacts would not change the relative net benefits of the Final Rule relative to the other options by more than $10 million.

We also looked at more extreme increases in productivity impacts: a doubling of all of the losses from the 2-night restart provision, and a very extreme case of a tripling of the losses (to an average of 1.50 hours per week for all of the drivers in the very high and extreme categories).

These changes increased the total estimated costs of the rule by 10 and 20 percent of the cost of the Final Rule, respectively, but would raise the benefits by at least as much in absolute terms. Thus, even extremely large (and, we believe, unrealistic) increases in the impacts of the 2-night restart provision would change the cost estimate only moderately, while leaving the estimated net benefits of the Final Rule at least as high and probably higher. Furthermore, we found that even large changes in the estimated productivity impact would have virtually no effect on the relative net benefits of the Final Rule compared to the other options.

In some previous analyses of the benefits of changes in HOS rule provisions, the Agency has calculated the safety consequences of hiring new drivers who are less experienced than the average existing driver. Because less experienced drivers have higher crash rates, the previous analyses found a small increase in crashes that offset part of the safety benefits of more restrictive HOS rule provisions. Those earlier analyses also found, however, an additional safety benefit from the shift of a small fraction of LH freight from trucks to rail, that results from more stringent HOS rule provisions. Because these two effects were found not only to be small, but to cancel each other out almost exactly, FMCSA did not consider them sufficiently important to include in this analysis. More detail on these analyses is presented in Sections 6.9 and 6.10 below.

Two other effects of the daily driving restriction are possible, but could not be analyzed with available information. First, for Options 2 and 4, limits of 10 or 9 hours of driving in a day could reduce the number of shipments that can be delivered in a single day with a single driver; and, for some shipments, this change in service characteristics could have a cost that is not included.

Lastly, no attempt was made to estimate effects on congestion; total driving is likely to drop slightly because higher rates for shippers are likely to lead to a small shift from truck to rail, while the requirement to take 2 nights off before restarting will in some cases encourage slightly more driving during the day.

6.5. SENSITIVITY OF NET BENEFITS TO CHANGES IN VSL

One form of sensitivity analysis we performed was to examine the sensitivity of the net benefits of Options 2 through 4 to different assumed VSL estimates. Guidance provided by DOT in 2009 suggested that a VSL of $5.8 million be used for regulatory analyses, and that sensitivity analyses be performed using a lower-bound VSL of $3.2 million and an upper-bound VSL of $8.4 million. Later in 2009, DOT suggested that the $5.8 million value should be raised to $6.0 million, but did not provide further guidance on the lower- and upper-bound VSLs [Szabat (2009)]. For this analysis, we scaled up the original lower- and upper-bound VSLs suggested by DOT to match the scaling up of the mean value from $5.8 million to $6.0 million. This resulted in a new lower-bound VSL of $3.3 million ($3.2 million × 1.03) and a new upper-bound VSL of $8.7 million ($8.4 million × 1.03). We calculated the net benefits of Options 2 through 4 using the different VSL assumptions for the three different baseline sleep assumptions and an assumption of a 13 percent baseline fatigue level, as shown below in Exhibits 6-18 through 6-20.

Exhibit 6-18. Net Benefits for Option 2 for Different VSL Assumptions (Millions 2008$)

Assumed VSL	Assumed Amount of Nightly Sleep		
	Low Sleep	Medium Sleep	High Sleep
Lower-bound VSL	-$180	-$420	-$650
Mean VSL	$400	-$20	-$450
Upper-bound VSL	$990	$370	-$250

Exhibit 6-19. Net Benefits for Option 3 for Different VSL Assumptions (Millions 2008$)

Assumed VSL	Assumed Amount of Nightly Sleep		
	Low Sleep	Medium Sleep	High Sleep
Lower-bound VSL	$60	-$100	-$250
Mean VSL	$440	$160	-$120
Upper-bound VSL	$830	$420	$20

Exhibit 6-20. Net Benefits for Option 4 for Different VSL Assumptions (Millions 2008$)

Assumed VSL	Assumed Amount of Nightly Sleep		
	Low Sleep	Medium Sleep	High Sleep
Lower-bound VSL	-$970	-$1,370	-$1,780
Mean VSL	-$50	-$790	-$1,520
Upper-bound VSL	$870	-$200	-$1,270

6.6. COSTS, BENEFITS AND NET BENEFITS OF RULE COMPONENTS AND PACKAGES

In addition to estimating the rule provisions as a complete package, we also examined the individual components of the rule and estimated the independent costs, benefits and net benefits for each. Because we considered the overlapping effects of the provisions in the above analysis, the sum of each individual rule component is greater than the costs, benefits and net benefits of the rule. The calculations are presented in more detail and across different assumptions of fatigue risk, sleep levels and discounting in Appendix C.

Exhibit 6-21 compares the individual component costs, benefits, and net benefits for the 7-day restart provision, the 2-night restart provision, and the 30-minute break provision independently, for packages of two of the three provisions, and for all three provisions. We round the values in Exhibit 6-21 to the nearest million to demonstrate the similarity in net benefits for some of these alternatives. First we considered the selected provisions separately with no overlapping effects. Next, we considered the provisions in packages of two, including overlapping effects. Finally, we compared the two methods to estimate the interaction effect of each grouping of the rule components.

Option 3, with all three provisions analyzed as a package, is shown to have net benefits of $205 million. That package with the 2 night provision removed (that is, including only the 7 day restart provision and the 30 minute break) appears to have marginally greater net benefits, at $206 million. Not shown in the table, however, are the substantial unmonetized benefits the 2 night provision is expected to have due to the circadian advantages of nighttime sleep. As noted in Section 6.4, these additional benefits were too complex to be quantified and monetized reliably. They would almost certainly be large enough, though, to ensure that the net benefits of the rule are improved by the inclusion of the 2 night provision. Similarly, the net benefits of a package that excluded the 30 minute break provision appears to be slightly greater than the net benefits of the Option 3 package, at $206 million. Again, the 30 minute break provision is expected to provide very substantial crash reduction benefits that could not be included in the analysis. These benefits, as noted in Section 6.4, are related to the short-term reductions in crashes provided by the break's restorative effects on alertness. If these short-term benefits could be monetized and added to the break's effects on cumulative fatigue, they would almost certainly show it to be a cost-beneficial addition to the rule.

Exhibit 6-21. Component and Interaction Costs, Benefits and Net Benefits For Option 3 (11-Hour Driving Allowed) (Millions 2008$)

Change from Current Rule Baseline	Costs*	Safety Benefits (13 Percent Fatigue)	Health Benefits (Medium Sleep Level, 7 Percent Discounting)	Net Benefits*
7-day restart alone	$342	$227	$318	$204
2-night restart alone	$51	$35	$38	$22
30-minute break alone	$94	$72	$94	$72
Sum of Option 3 provisions, taken separately	$487	$334	$450	$297
Option 3 analyzed as a package	$426	$282	$349	$205
Overlap among Option 3 provisions (difference between sum of separate provisions and package)	$62	$52	$102	$92
Sum of 7 day and 2 night provisions, taken separately	$393	$262	$356	$225
7 day and 2 night provisions, analyzed as a package	$393	$260	$340	$206

Overlap between 7 day and 2 night provisions (difference between sum of separate provisions and package)	$0	$2	$17	$19
Sum of 7 day and 30 minute provisions, taken separately	$436	$299	$412	$276
7 day and 30 minute provisions, analyzed as a package	$374	$253	$328	$206
Overlap between 7 day and 30 minute provisions (difference between sum of separate provisions and package)	$62	$47	$84	$69
Sum of 2 night and 30 minute provisions, taken separately	$145	$107	$132	$94
2 night and 30 minute provisions, analyzed as a package	$145	$95	$127	$76
Overlap between 2 night and 30 minute provisions (difference between sum of separate provisions and package)	$0	$12	$5	$17

* Does not include the $40 million in reprogramming costs.
Note: Totals do not add due to rounding.

6.7. Sensitivity of Results to Changes in Baseline Crash Risk

The estimated safety benefits of this rule were based on multiplying estimated percentage changes in crash damages by the total annual damage attributable to LH truck crashes. The total damages, in turn, were calculated based on estimated average damage per large truck crash times the annual number of large truck crashes. The damage per crash and annual number of crashes were taken, as explained in Section 4.4, from a comprehensive 2007 report to FMSCA on the cost of large truck crashes. That report, though it is the most recent available study that looks comprehensively at damages from large truck crashes, used crash data from the years 2001 through 2003.

Commenters pointed out that crashes have been falling in recent years after the 2003 HOS rules took effect, and that using more recent crash experience would lower the projected benefits of the rule. In response, FMCSA has reviewed the issue of the number of annual crashes. As shown in Exhibit 6-22, after total crashes moved up and down in the first half of the last decade, they began declining in the second half. The last two years in the series, however, were dominated by a severe recession, which reduced both demand for trucking and the number of other vehicles on the road. A reasonable comparison of crashes before and after the change in rules would be the years 2001 through 2003, as used by Zaloshnja & Miller (2007), and 2004 through 2007.

Exhibit 6-22. Large Truck Crashes by Type of Crash, 2001 to 2009

Year	Fatals	Injury	Property Damage Only	All
2001	4,451	86,000	319,000	409,451

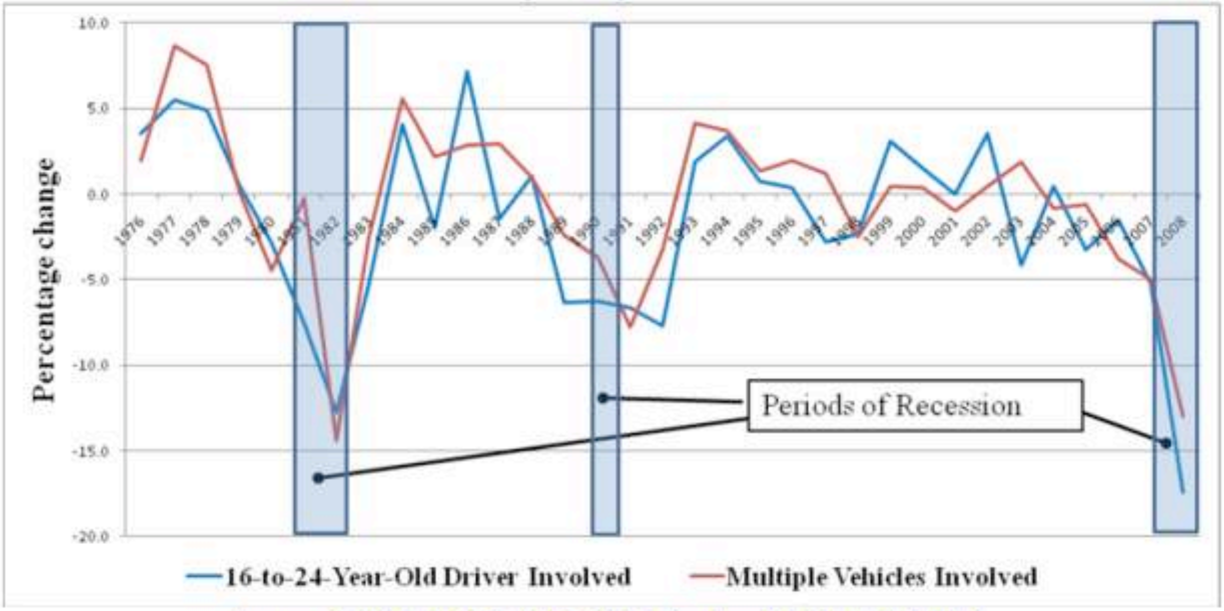
2002	4,224	90,000	322,000	416,224
2003	4,335	85,000	347,000	436,335
2004	4,478	83,000	312,000	399,478
2005	4,551	78,000	341,000	423,551
2006	4,350	77,000	287,000	368,350
2007	4,204	72,000	317,000	393,204
2008	3,754	64,000	297,000	364,754
2009	2,987	51,000	232,000	285,987
Average 2001 - 2003				420,670
Average 2004 - 2007				396,146
Ratio				94%

Numbers taken from FMCSA's Large Truck and Bus Crash Facts 2009 – available online at http://www.fmcsa.dot.gov/facts-research/LTBCF2009/LargeTruckandBusCrashFacts2009.aspx

There were about 6 percent fewer total crashes in the latter period than in the former. If the only change made to the benefits analysis were to reduce the total estimated number of crashes, then, the safety benefits would decline by 6 percent.

To illustrate why recession years may be problematic, we reproduce a graph of multi-vehicle crashes with recessionary periods highlighted taken from a recent NHTSA Study. As can be seen, multi-vehicle fatal crashes have declined sharply in every recession, going back to the 1970s, only to rebound when the economy returned to normal. Given this finding we are reluctant to use the data from 2008 and 2009, because doing so would be likely to artificially depress benefits compared to a typical year.

Figure 10: Percentage Change in Fatal Multiple Vehicle Crashes and Percentage Change in Fatal Crashes Involving Young Drivers, 1975 to 2008



Source: NCSA FARS 1975-2007 Final and 2008 ARF, BLS

FMCSA has not adjusted for this trend for three reasons. First, the count of fatal accidents involving trucks that the agency used to estimate benefits is based on FARS data; when these data are reexamined for the TIFA analysis, the researchers identify several hundred fatal accidents a year that are not included in the FARS data as truck accidents. The analysis, therefore, undercounts fatal accidents across time. Second, NHTSA has stated that about half of the injury and property damage only accidents are never reported by the States. Although these are generally believed to be minor crashes, minor damage or injuries result in costs that, if accounted for even at a low level, would increase the baseline cost of other accidents by as much or more than the downward trend would represent. Finally, the number of crashes is not the only factor to have changed; both the mix of crashes over time is different (e.g., fatal crashes actually rose between the two periods), and the costs associated with different categories of damages (such as medical costs) have changed at rates that are not adequately accounted for by an inflation adjustment. These shifts mean that, in the absence of a comprehensive new analysis of crash damages, a simple adjustment in the number of crashes would not necessarily be accurate.

Still, to test whether it would be worth recomputing the value of crashes for the more recent period, FMCSA conducted a sensitivity analysis of the effects of reducing crash damages (and hence safety benefits) by 6 percent. This sensitivity analysis showed only slightly lower benefits and net benefits. For example, for the 13 percent fatigue/medium sleep case, the total annual benefits (and net benefits) of Options 2, 3, and 4 fell by $36, $17, and $68 million, respectively. These changes were only 2.7% to 4.5% of total benefits, and had no effect on whether the options were cost effective, or which options were the most cost effective.

We also recomputed the value of crashes using the median number of crashes for the two respective time periods, including recessionary years. This resulted in a reduction of about

9 percent in the baseline number of crashes. Again, for the 13 percent fatigue/medium sleep case, the total annual benefits (and net benefits) of Options 2, 3, and 4 fell by $49, $23, and $93 million, respectively. These changes were only 3.9 percent to 6.8 percent of total benefits, and also had no effect on whether the options were cost effective, or which options were the most cost effective. Thus, FMCSA determined that changing this factor was not crucial to the analysis in any way. Exhibit 6-23 presents the estimated safety benefits and net benefits for each option using the median number crashes for both the 2001 to 2003 and the 2004 to 2009 periods.

Exhibit 6-23. Comparison of Safety and Net Benefits Using Different Crash Data

HOS Options	Estimates Based on 2001 to 2003 Crash Data		Estimates Based on 2004 to 2009 Crash Data	
	Safety Benefits	Net Benefits	Safety Benefits	Net Benefits
Option 2	$580	-$50	$530	-$100
Option 3	$270	$150	$250	$130
Option 4	$1,090	-$830	$1,000	-$920

6.8. SENSITIVITY OF RESULTS TO ASSUMPTIONS FOR ELIMINATION OF FATIGUE

The net benefit estimates shown above assume that any crash that involves or is related to fatigue will be prevented if the fatigue driver involved in the crash is eliminated. We conducted an additional sensitivity analysis to determine what the benefits of the rule would be under a different assumption about the percent of fatigue-involved crashes that would be prevented if fatigue is eliminated. Exhibits 6-24 through 6-26 show the safety benefits, annual total benefits, and annual net benefits for Option 2 under the original assumption that 100 percent of fatigue-related crashes would be eliminated, and also for an alternate assumption that only 50 percent of fatigue related crashes would be eliminated.

Exhibit 6-24. Safety Benefits for Option 2
(13 Percent Baseline Fatigue Risk) (Millions 2008$)

Assumed Percent of Fatigue-involved Crashes Prevented if Fatigue is Eliminated	Benefits due to Reduced Daily Time on Task Effect[a]	Benefits due to Reduced Weekly Time on Task Effect[b]	Total Benefits due to Reduced Crashes
100%	$210	$390	$600
50%	$110	$200	$310

a. Acute fatigue from long hours in a day

b. Cumulative fatigue from long hours over many days

Exhibit 6-25. Annual Benefits for Option 2 (13 Percent Baseline Fatigue Risk) (Millions 2008$)

	Assumed Baseline Amount of Nightly Sleep		
Assumed Percent of Fatigue-involved Crashes Prevented if Fatigue is Eliminated	**Low Sleep**	**Medium Sleep**	**High Sleep**
100%	$1,410	$980	$550
50%	$1,111	$680	$250

Exhibit 6-26. Annual Net Benefits for Option 2 (13 Percent Baseline Fatigue Risk) (Millions 2008$)

	Assumed Baseline Amount of Nightly Sleep		
Assumed Percent of Fatigue-involved Crashes Prevented if Fatigue is Eliminated	**Low Sleep**	**Medium Sleep**	**High Sleep**
100%	$400	-$20	-$450
50%	$100	-$320	-$750

6.9. SUMMARY OF RESULTS FOR OPTIONS 2 THROUGH 4

In this section, we present a brief summary of the results for Options 2 through 4. First, total costs of Options 2 through 4 are shown in Exhibit 6-27.

Exhibit 6-27. Annualized Costs of All Options (Millions 2008$)

	Option 2: 10 Hours of Driving Allowed	Option 3: 11 Hours of Driving Allowed	Option 4: 9 Hours of Driving Allowed
Total Costs	$1,000	$470	$2,290

Next, the total benefits of the different options are shown in Exhibit 6-28. Benefits for Options 2 through 4 are shown using different assumptions on the baseline level of sleep by drivers.

Exhibit 6-28. Benefits of All Options (13 Percent Baseline Fatigue Risk) (Millions 2008$)

Benefit Category	Option 2: 10 Hours of Driving Allowed	Option 3: 11 Hours of Driving Allowed	Option 4: 9 Hours of Driving Allowed
Benefits with Low Sleep	$1,410	$910	$2,240
Benefits with Medium Sleep	$980	$630	$1,500
Benefits with High Sleep	$550	$350	$770

Next, Exhibit 6-29 shows the net benefits of the alternative options under the different assumptions of the baseline level of sleep. It is interesting to note that net benefits are negative for Option 2 under the assumption of high levels of baseline sleep for drivers, and are negative for Option 4 under the assumption of medium and high levels of baseline sleep.

Exhibit 6-29. Net Benefits of All Options (13 Percent Baseline Fatigue Risk) (Millions 2008$)

Net Benefit Category	Option 2: 10 Hours of Driving Allowed	Option 3: 11 Hours of Driving Allowed	Option 4: 9 Hours of Driving Allowed
Benefits with Low Sleep	$400	$440	-$50
Benefits with Medium Sleep	-$20	$160	-$790
Benefits with High Sleep	-$450	-$120	-$1,520

6.10. MODE SHIFT IMPLICATIONS OF HOS OPTIONS

By reducing driver productivity, the HOS options are expected to increase the costs of freight transportation by truck. These costs, in turn, are likely to be passed on to shippers as rate increases. The increases in rates will tend to change the balance between truck and rail modes of transporting certain commodities, leading to a small shift in freight from truck to rail.

This effect was analyzed in detail for the 2003 HOS rule using a logistics model and taking into account both the effects of productivity changes and the wage increases likely to be needed to attract additional drivers. The following section explains in some detail how that analysis was conducted.

The possibility that changes in HOS could raise the cost of shipping by truck enough to encourage a shift to rail was considered explicitly in FMCSA’s analysis of the 2003 HOS rules. This section provides background on that analysis, taken largely from Appendix C to the 2003 RIA, and discusses how the analysis has been applied to the current rules.

6.10.1 The Logistics Cost Model

To determine the effects of the HOS rules on the mode split between truck and rail, we used the Logistics Cost Model (LCM) developed by Paul Roberts. The LCM is a computer model that determines the total logistics cost of transporting a product from a vendor to a receiver. The model determines the lowest cost for ordering, loading, transporting, storing, and holding a product. The shipper is assumed to select the alternative that minimizes total logistics costs. Total logistics cost in this case includes the costs occasioned by service frequency, transit time, reliability, loss and damage, spoilage, and other service-related factors occurring during ordering, transport, or storage. By converting all of these factors into their quantitative impacts on total logistics cost, the tradeoffs among service quality, inventory carrying and transportation charges can be addressed. The variables affecting the choices of the shipper are used to develop each of the individual cost factors listed on the right hand side of Exhibit 6-30.

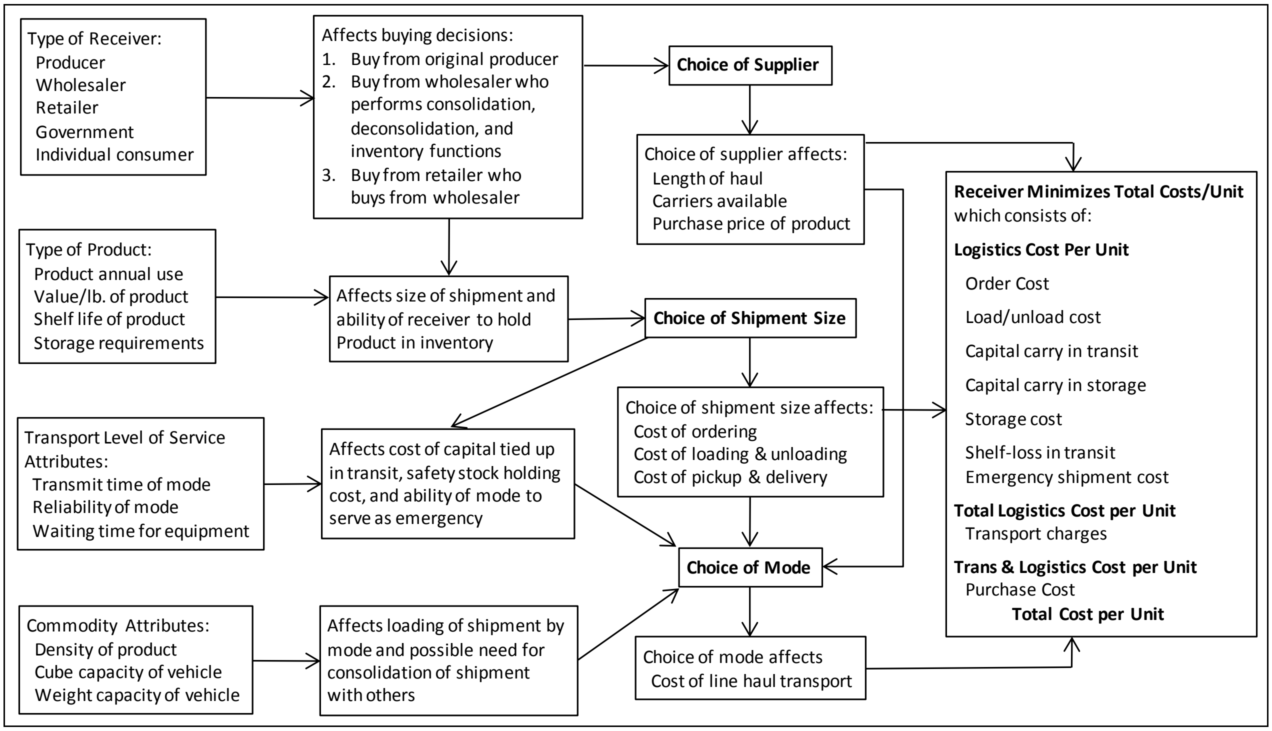


Exhibit 6-30. Variables affecting choices in freight transportation.

These variables are used to write equations for each of the components of total logistics costs as a function of the principal choice variables (i.e., choice of supplier, choice of mode, and choice of shipment size). Changes in transport charges lead to changes in logistics costs to give the total logistics-cost change of an option. Within the model, some "shippers" make new choices and the change in mode share is calculated for the sample in the model.

6.10.2 Computational Steps

The model is organized to use a variety of inputs in a decision process to develop the total logistics costs of a single movement. Computational steps used by the model include the following:

- For a shipper with a given annual use of a particular product, consider alternative mode and shipment size possibilities from the vendor, including LTL, TL, intermodal rail, and rail carload.
- Use rate models for alternative modes to develop transportation charges to the shipper.
- Develop level of service attributes for each source/mode/shipment size, including frequency of service/waiting time, transit time, lead time reliability, and probability of loss and/or damage.
- Combine with attributes of the product being shipped, including units, cube/unit, packed density/unit, value/unit, and shelf life.
- For each alternative source/mode/shipment size, develop the components of total logistics cost to the user of the product for factors including ordering, transporting, carrying costs, storage, and perishability.
- Sum to yield total logistics cost of each alternative.

6.10.3 Data Used

The LCM is a disaggregated model. The model uses a representative sample of individual movements; the data include shipper characteristics, feasible modal alternatives, movement parameters, and commodity attributes for each movement. A disaggregate sample allows the model to examine all of these characteristics and correctly select the mode that minimizes the shipper's total logistics costs.

Two different disaggregate data sources were used to assemble the data set used in the analysis. One is the Rail Carload Waybill Sample. These data are a sample of individual rail movements of various products moving in various car types between various origins and destinations throughout North America. Two data sets were extracted from the Waybill Sample for use in this analysis. The first was a sample of rail carload movements, excluding coal. The second was a set of intermodal rail movements. In all, 2,556 rail movements were used.

A disaggregated sample of LH TL movements gathered by the Association of American Railroads in 1994 was used to establish the composition of truck shipments with regard to commodity, equipment type, and shipment size. The sample was obtained by interviews of LH truck drivers taken at selected truck stops throughout the United States. The information gathered in each of the interviews included the commodity being carried, the origin, the destination, the type of truck and a variety of information about driver and vehicle. A total of 3,784 movements were eventually used, representing LH TL movements throughout the nation. The data set developed by Reebie Associates, reflecting freight flows in 2000, was used to adjust the relative volume of traffic flows among origin-destination pairs to reflect current conditions.

The analysis was limited to movements of 250 miles or more. This was done on the grounds that the probability of switching traffic from truck to rail is effectively zero for moves under 250 miles. Most authorities would assert, in fact, that this probability is quite low for shipments under 500 to 700 miles. Two hundred fifty miles was chosen as a minimum, however, to ensure a thorough analysis. Data on length of freight movements from the 1997 CFS were used to adjust the disaggregate data set so that the sample of moves more than 250 miles would conform to actual practice in the relative volumes of such traffic among city pairs.

6.10.4 Results of Using the Logistics Cost Model

Results from the analysis allowed us to observe which individual moves are diverted from truck as the cost of trucking goes up, and which are diverted to truck when the cost of trucking drops. For our purposes the results are aggregated and expanded to determine the increase or decrease in truck usage as a result of changes in HOS policy. Exhibit 6-31 below shows the result of exercising the model throughout a range of increases and decreases in overall truck costs. Five cases are covered: the base case (the current level of truck cost); 1.0 and 2.0 percent increases from the base cost, and 1.0 and 2.0 percent decreases from the base cost. The results are presented in Exhibit 6-31. Both truck shipments and tons are greater in the cases with costs below the base case, and lower in the cases with higher costs, but to only a small degree.

Observations

	Rail	Intermodal	Truck	Totals
Base Case	547	2,009	3,784	6,340
1.01*Base	552	2,070	3,718	6,340
Base*1.02	560	2,111	3,669	6,340
Base*.99	537	1,957	3,846	6,340
Base*.98	519	1,921	3,900	6,340

Tons

	Rail tons/yr	Intermodal tons/yr	Truck tons/yr	Totals
No. Tons in sample				
Base Case	2,221,349	2,710,958	8,307,492	13,239,799
1.01*Base	2,238,476	2,801,360	8,199,963	13,239,799
Base*1.02	2,260,564	2,870,570	8,108,665	13,239,799
Base*.99	2,181,121	2,623,090	8,435,588	13,239,799
Base*.98	2,128,862	2,543,339	8,567,599	13,239,799

Exhibit 6-31. Summary of model runs.

The results of these analyses were used to estimate elasticities for the response of total truck and rail traffic to changes in overall truck costs. The ratio of the percentage change in truck shipments and tons shipped, per 1 percent change in truck rates, was approximately 1.4. This measure of elasticity was used, in turn, to estimate impacts on truck and rail traffic for each of the HOS rule options.

In the analysis for the 2003 HOS rules, the proposed Option was estimated to reduce truck rates by 0.3 percent; applying the elasticity of 1.4 to this reduction would lead to about a 0.4 percent increase in the relevant LH segment (i.e., those greater than 250 miles). Across all LH segments, the increase would be a somewhat smaller 0.25 percent.

6.10.5 Scaling of the Results of the Mode Shift Analysis

Because the measured effect in that analysis was small, FMCSA did not consider it necessary to repeat the analysis in detail. Rather, the mode shift effect of the new rule has been estimated by scaling the results of the previous analysis in recognition of the differences between the costs of the options in 2003 and 2010.

In the analysis for 2003, both the Parents against Tired Truckers (PATT) Option and the Full Compliance Baseline were found to reduce LH truck VMT because of their costs relative to the Status Quo Baseline (which was also the No Action Alternative). As shown in the Environmental Assessment for the 2003 HOS Rules, the PATT Option would lead to a LH truck VMT reduction of 1.35 percent, while the corresponding LH truck VMT reduction for the Full Compliance Baseline would be only 0.84 percent [FMCSA (2002b)].[35] The difference is a reduction in LH truck VMT by an incremental 0.51 percent. The difference in productivity for LH truck drivers between these two scenarios was 4 percent, as shown by the 4 percent increase in drivers required to transport a given amount of freight under the PATT Option relative to the Full Compliance Baseline.[36] Dividing the 0.51 percent change in VMT by the 4 percent drop in productivity yields just under 0.13, which is the ratio of VMT changes to productivity changes that is used in the current analysis. Thus, a reduction in productivity of 2.8 percent for Option 2 is projected to lead to a small mode shift that would reduce LH VMT by 0.36 percent (0.13 × 2.8). This small drop in VMT would offset some of the need for additional drivers caused by the reduction in LH productivity. Compared to Option 2, Option 3 would lead to a drop in LH VMT and drivers about half as great (in line with its lower costs) and Option 4 would lead to drop about twice as great.

6.11. CHANGE IN DRIVERS

The operational changes resulting from the HOS rule provisions reduce the productivity of drivers that are close to or above the maximum daily driving and work time limits. Assuming there is no change (except for some mode shifting as discussed above) in the amount of freight that needs to be moved, new drivers will need to enter the industry under Options 2 through 4.

To calculate the number of new drivers that would be needed for Options 2 through 4, we multiplied the total number of drivers (1,600,000) by the estimated percent impact on productivity. This calculation resulted in an estimate of the gross number of new drivers that would be needed for Options 2 through 4. For example, for Option 3 there is an estimated 1.19 percent impact on industry productivity. The gross number of new drivers needed for this regulatory option is thus 19,116 (1,600,000 × 1.19%).

We next calculated the net number of new drivers by accounting for the mode shift effects. Using the ratio of VMT change to productivity change discussed above results in 87 percent

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[35] Because some of the projected impact on LH VMT was assumed to result indirectly from changes in short-haul productivity, operating through the labor market, this estimate of the mode shift consequences of the productivity changes in the LH segment is slightly overstated.

[36] 2003 HOS RIA [FMCSA (2002a)], Exhibit 9-1, Changes in Drivers Needed in Response to HOS Limits Relative to Current Rules with Full Compliance.

(100% - 13%) of the total number of new drivers needed after accounting for mode shift effects. For example, for Option 2, the net number of new drivers needed is 16,631 (19,116 × 87%). Exhibit 6-32 below presents the gross and net number of new drivers needed for Options 2 through 4.

Exhibit 6-32. Gross and Net Numbers of New Drivers Needed

Net Benefit Category	Option 2: 10 Hours of Driving Allowed	Option 3: 11 Hours of Driving Allowed	Option 4: 9 Hours of Driving Allowed
Estimated Productivity Impact (A)	2.69%	1.19%	6.30%
Gross Number of New Drivers Needed (B = A × 1,600,000)	43,104	19,116	100,814
Net Number of New Drivers Needed (C = B × 87%)	37,500	16,631	87,708

6.12. SAFETY IMPACTS OF NEW DRIVERS AND MODE SHIFTS

As stated in Section 6.4, both the small projected shift from truck to rail and the substitution of new drivers for some of the work currently done by experienced drivers can be expected to have minor safety consequences. This section goes into more detail on the past analyses that found that these effects largely offset each other.

6.12.1 Safety Impacts of New Drivers

The analysis for the 2003 HOS rules explicitly considered the safety consequences of expanding the driver population by hiring inexperienced drivers. Data from a survey by the University of Michigan Trucking Industry Program on years of experience and crashes showed rapidly declining crash risk as new drivers gain experience, and then a gradual increase as the drivers age [Belman (1997-1999)]. These data were used to develop the quadratic function shown in Exhibit 6-33. The function, in turn, was used to estimate the average risk during the next 10 years for both new drivers and drivers who start with 4 years of experience, each relative to the risks of a brand-new driver. These calculations showed that the average risk for new drivers for the first 10 years of their experience is 19.6 percent below the first year, and the 10-year average of drivers who start with 4 years of experience is 31.5 percent below the first year. Blending those brand-new and somewhat new drivers in the ratio of 85% / 15% (based on conversations with industry sources) gave a weighted average of 21.4 percent below the first year for the new drivers during the first 10 years.

To compare this risk reduction level to that for the population as a whole, the quadratic function was combined with data on driver experience from the Driver Fatigue, Alertness and Countermeasures Study [Abrams, *et al.* (1997)]. Plugging various numbers of years of experience into the quadratic function for reduction of risk below the first year, and then weighting by the distribution of the existing driver population, the typical existing driver was found to be 28.2 percent less likely to crash than a brand new driver. The difference between the new and the existing drivers, then, is (28.2% - 21.4%) or 6.8 percent. This difference is then the predicted increase in crash risk for the new drivers relative to the existing drivers. Because this risk increase applies only to the new drivers, who constitute a fraction of the total population, the effect on total crash damages and total fatalities is very small. In the 2003 RIA, the impact was expressed in terms of changes in benefits. The proposed option was projected to lead to a reduction in LH drivers of 3.9 percent, or 58,500; applying the slightly lower crash risk for existing drivers to this reduction in new drivers led to a projected reduction in total LH crash damage of 6.8% × 3.9% or 0.265 percent. At the time, total damages from LH crashes were estimated at $18.7 billion per year, so the reduction of 0.265 percent translated to a reduction in crash damage of about $50 million per year. Alternatively, the effect of reducing the driver population by 58,500 could have been translated into lives saved: 0.265 percent of the 3,100 fatalities in LH crashes equals about 8 lives.

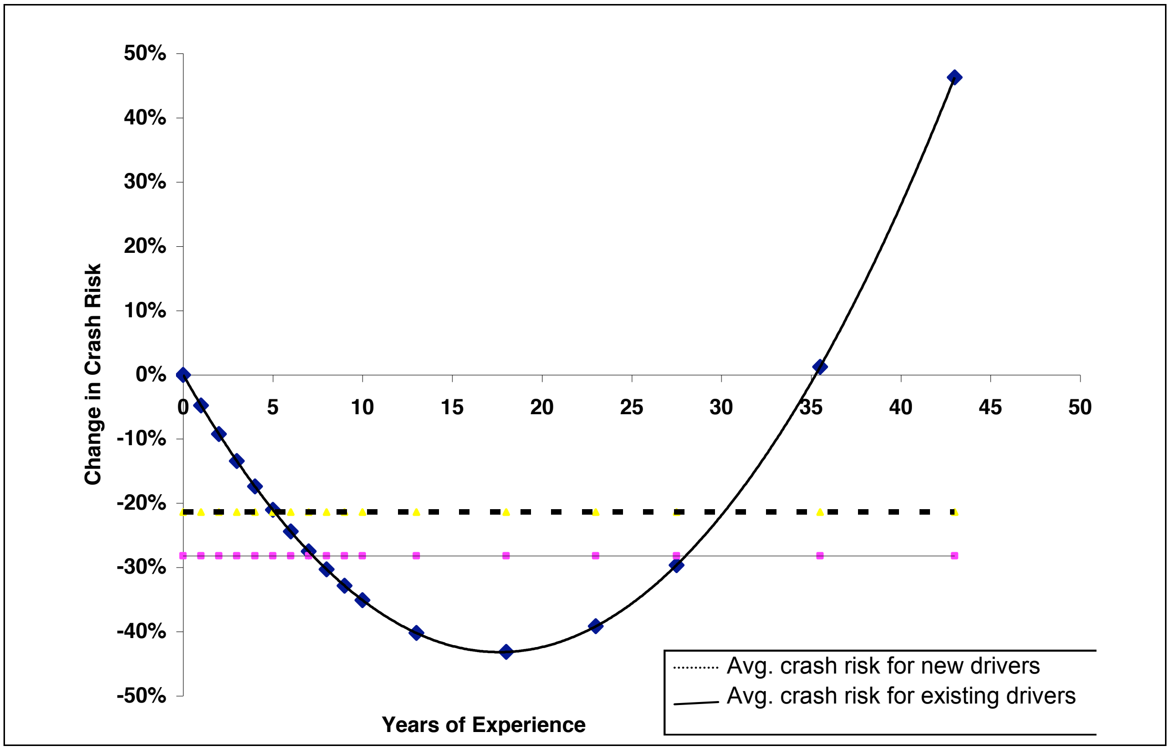

Exhibit 6-33. Effect of experience on crash risk.

Source: From Exhibit 8-11 of the 2003 RIA; ICF analysis of University of Michigan Trucking Industry Program and the Driver Fatigue, Alertness and Countermeasures Study data.

6.12.2 Safety Impacts of Mode Shift

Counteracting the change in risk from different numbers of new drivers is the change in truck VMT that results from mode shifts between truck and rail. As presented in Section 6.7.4 above, the mode shift analysis for the 2003 HOS rules found that the proposed option would increase truck VMT by about 0.25 percent. Assuming that, other things equal, crashes are proportional to VMT, this increase would increase fatalities related to LH crashes by 0.25 percent of their baseline level of about 3,100, and increase total damages from LH crashes by 0.25 percent of

$18.7 billion. Multiplying 0.25% × 3,100 gives an estimated increase of just below 8, and 0.25% × $18.7 billion gives an increase of $47 million.

These changes would cancel out, almost exactly, the benefits of reducing the number of slightly riskier new drivers, which as noted were 8 lives and $50 million. The small magnitude of the effects of the new drivers on the one hand and the mode shift on the other, the fact that they were found to operate in opposite directions, and appeared (when estimated carefully) to offset each other almost completely, led FMCSA to conclude that explicitly analyzing these effects for the 2010 HOS Rule was unnecessary.

7. Regulatory Flexibility Analysis

As required by the Regulatory Flexibility Act (RFA), this chapter analyzes the impact of the changes to the HOS regulations on small entities. After a statement of the need for, and objectives of, the rule, and statements regarding responses to comments, we then discuss the possible number of affected small entities. We next estimate the impact of the new HOS rule provisions on small carriers in the first year in which the rule would be in effect for Option 3. We then estimate the annual burden on small entities during the first 10 years of the rule being in effect. Lastly, we discuss the reporting, recordkeeping, and other compliance requirements of the new rule, discuss whether any other Federal regulations overlap with it, and discuss the consideration of alternatives to minimize its impact on small entities.

7.1. A statement of the need for, and of, the rule

The objectives of the changes to the HOS rule are to improve safety while ensuring that the requirements do not have an adverse impact on driver health. The impact of HOS rules on CMV safety is difficult to separate from the many other factors that affect heavy-vehicle crashes. While the Agency believes that the data show no decline in highway safety since the implementation of the 2003 HOS rule and its re-adoption in the 2005 HOS rule, the 2007 IFR, and the current HOS rule (73 FR 69567, 69572, Nov. 19, 2008), the total number of crashes, though declining, is still unacceptably high. Moreover, the source of the decline in crashes is unclear. FMCSA believes that the required break during long days, and the limits on extreme weekly hours, the modified HOS rules, coupled with FMCSA's many other safety initiatives and assisted by the actions of an increasingly safety-conscious motor carrier industry, will result in continued reductions in fatigue-related CMV crashes and fatalities. Furthermore, the changes in the rule are intended to protect drivers from the serious health problems associated with excessively long work hours, without significantly compromising their ability to do their jobs and earn a living.

7.2. A summary of the significant public issues in response to the RFA raised by the public comments in response to the RFA, a summary of the assessment of the agency of such issues, and a statement of any changes made in the proposed rule as a result of such comments.

Comments. Very few commenters directly addressed the Initial RFA analysis. Commenters generally stated that the rule would affect revenues of carriers, but these impacts were not specific to small entities. Shippers and receivers also argued that they would be affected, but these entities are not subject to FMCSA regulations and are not, therefore, considered in the RFA analysis. The Petroleum Marketers Association of America stated that the changes to the restart provision would have a serious impact on small heating oil and propane suppliers. They would need to hire extra drivers to cover emergency deliveries.

FMCSA Response. As stated in previous responses, the restart provision will affect only drivers working extreme hours. Without information on the hours being worked by drivers for fuel retailers, it is difficult to assess whether they will be affected, but most local drivers do not work 60 to 70 hours a week and, therefore, are not limited by the restart provision. In any case, drivers of CMVs used primarily in the transportation of propane for winter heating are statutorily exempt from most of the regulations in the FMCSRs if compliance with those regulations would prevent the driver from responding to an emergency condition requiring immediate response (see 49 CFR 390.3(f)(7)).

7.3. The response of the agency to any comments filed by the Chief Counsel for Advocacy of the Small Business Administration in response to the proposed rule, and a detailed statement of any change made to the proposed rule in the final rule as a result of the comments.

The Office of Advocacy at SBA filed comments that were a summary of concerns raised by industry at a roundtable that it hosted on February 9, 2011. As SBA indicated, the comments are "nearly identical to many of those expressed at FMCSA's public listening session on the proposed rule…." Summarized the points as follows:

- The proposed rule is not supported by existing safety and health data.
- The proposed rule would reduce flexibility and could actually impede safety and driver health by increasing the stress on drivers as they try to work within the limits.
- The proposed rule would be operationally disruptive and costly.
- Truck related accidents are decreasing under the current rules, even while truck miles driven have increased.

As has been stated throughout the preamble, FMCSA disagrees strongly with these industry claims. The rule is supported by research on accidents and the health effects of long hours on health. Research on the effects of long work hours on accident rates, both for drivers and for other workers clearly indicate that risk rises after 8 hours of work. The research on the health effects of sleep loss and long hours is also extensive.

On the idea that the limits put stress on drivers, the Agency notes that any limit will do this for a driver who is working to the limits. The only way to remove this stress is to allow drivers and carriers to work as many hours as they want regardless of the safety consequences. Research has shown that drivers (and everyone else) have very little ability to accurately assess their own fatigue levels, as is also evidenced by the high percentage of CMV drivers who admit to falling asleep at the wheel. Today's rule allows the hardest working drivers to average 70 hours a week, which is surely enough.

The claims of serious operational disruptions are unsupported by any data and contradicted by the industry's own statements that the provisions at issue are not used by most drivers. SBA noted that carriers are subject to factors beyond their control, such as loading dock availability. FMCSA recognizes that carriers cannot control shippers and receivers, but allowing drivers to work extreme hours is not a reasonable solution to that problem. On SBA's final point, Section IV A of this preamble discusses the flaws in this argument at length. FMCSA has made changes to the final rule to reduce the complexity of the rule and provide some flexibility. The periods required under the 2-night restart provision are 2 hours shorter than proposed; this change will provide more flexibility for drivers who work at night irregularly. Most drivers who have regular nighttime schedules already take 2 nights off a week and do not need to use the restart provision. The final rule also changes the break requirement to make it easier for drivers using the split sleeper berth provision. Finally, FMCSA has removed the 13-hour duty time limit to reduce the complexity of the final rule.

7.4. A description and an estimate of the number of small entities to which the rule will apply or an explanation of why no such estimate is available.

The HOS regulations apply to both large and small motor carriers. The SBA defines a small entity in the truck transportation sub-sector (North American Industry Classification System [NAICS] 484) as an entity with annual revenue of less than $25.5 million [13 CFR 121.201]. Using data from the 2007 Economic Census, FMCSA estimated that the average carrier earns roughly $160,000 in annual revenue per truck for firms with multiple power units,[37] suggesting that a typical carrier that qualifies as a small business would have fewer than 141 ($25.5 million / $160,000) power units (i.e., trucks or tractors) in its fleet. From the 2007 Economic Census data on non-employer firms, sole proprietorships earn approximately $107,700 in annual revenue.

To determine the number of affected small entities, we used the analysis conducted by FMCSA for the Unified Carrier Registration (UCR) rule.[38] The economic analysis for the UCR rule divided carriers into brackets based on their fleet size (i.e., number of power units), and estimated the number of carriers in each bracket. These brackets and their corresponding numbers of carriers are shown in Exhibit 7-1. According to these estimates and the above-mentioned characterizations of small entities in the trucking industry, all of the carriers in Brackets 1 through 4 would qualify as small entities, as would many of the carriers in Bracket 5.

Exhibit 7-1. Number of Carriers by Fleet Size (From FMCSA's Analysis of the UCR Rule)

Bracket	Fleet Size	Number of Carriers
1	1	194,425
2	2 – 5	145,266
3	6 – 20	65,155
4	21 – 100	17,350
5	101 – 1,000	3,590
6	1,001 – More	292
Total		**433,535**

Therefore, this analysis estimates that between 422,196 (Brackets 1 through 4) and 425,786 (Brackets 1 through 5) small entities would be affected by the HOS rule changes. This range overstates the number of affected small entities for several reasons. First, many private carriers

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[37] See Appendix A for the derivation of the revenue per firm with multiple power units. A firm with one power unit and two drivers would have even higher revenues per truck because the two drivers could drive more hours than a firm with a single driver.

[38] FMCSA, "Regulatory Evaluation of the Fees for the Unified Carrier Registration Plan," February 19, 2010. Available in the docket: FMCSA-2009-0231-0181.

with small fleets may not qualify as small businesses because their primary business is not the movement of freight. These private firms have other sources of revenue and fall under different NAICS codes; for example, one of the largest pharmacy chains has fewer than 141 power units, but is not a small entity. Second, the carriers are allowed to register by location so that a single firm may have multiple DOT registrations, each of which appears to be small, but which at the firm level represents a large entity. Third, the carrier numbers include firms that are not subject to this rule, such as passenger-carrying carriers and utilities, or are subject to only part of the rule (e.g., construction firms have a different restart provision).

Exhibit 7-2 presents figures for private carriers by NAICS code for industries with large numbers of drivers (and hence the likelihood of large numbers of fleets). The table includes the total number of CMV drivers working in each industry, the percentage of payroll those drivers account for, and the payroll of those industries as a percent of total industry revenue. Some of these industries have SBA size thresholds that are considerably lower than the threshold for truck transportation, strongly suggesting that many firms in these industries that would be considered small using the threshold of 141 power units are actually large. For example, a wholesaler with 141 trucks is certainly a large firm because it will have more than 100 employees. Other industries have thresholds as high as 1,500 full-time equivalent employees (FTEs); a firm in one of these industries might rank as small with even more than 141 power units if the number of power units in its fleet were large compared to the size of its workforce (e.g., if it had 300 power units, and only three employees per power unit, it could be considered small in an industry with a threshold of 1,500 FTEs). From Exhibit 7-2, however, this circumstance is not likely to be common: in firms in NAICS 21 and 31-33, which have high FTE thresholds, drivers make up only a very small percentage of the workforce. Thus, firms with a substantial numbers of power units are likely to have much larger labor forces, and are therefore likely to rank as large firms.

Exhibit 7-2. Private Carriers and Drivers by Industry

NAICS	Industry	SBA Standard	# Drivers	Drivers as % of All Employees	Payroll as % Revenues
21	Mining, Quarrying, and Oil and Gas Extraction	500 FTE	29,900	4.17%	10%
23	Construction	$14m-$33.5m	127,200	1.76%	19%
31-33	Manufacturing	500-1,500 FTE	238,600	1.78%	11%
42	Wholesale	100 FTE	509,000	8.53%	5.5%
44-45	Retail	$7 m - $29m	307,900	2.01%	10%
53	Real Estate and Leasing	$7m - $25m	40,500	1.90%	18%
56	Administrative and Support and Waste Management and Remediation Services	$7m – $35.3m	132,300	1.64%	46%
722	Food Services	$7m	175,400	1.82%	29%
81	Other Services	$7m	44,000	0.80%	24%

Given these considerations, we are, if anything, over-counting the number of private carriers that would qualify as small businesses.

7.4.1. First Year Impacts on Small Entities

Affected small entities would incur several types of costs as a result of the HOS rule provisions. First, as discussed in the HOS RIA, carriers would incur annual costs due to losses in productivity. As discussed in the HOS RIA, these productivity impacts are roughly $430 million (not including the one-time cost for training requirements) per year for Option 3. We divided this total productivity impact by the approximate number of LH drivers (1,600,000) to obtain an annual per driver productivity impact of approximately $270. We then converted these per driver impacts to per power unit impacts (shown below in Exhibit 7-3). For sole proprietorships, we assumed for this analysis that these were single power unit firms and there was one driver per tractor. The total annual operational cost for sole proprietorships was thus $270 ($270 × 1) for Option 3.[39] For firms with multiple power units, this analysis assumes that multiple unit carriers have 1.1 drivers per power unit [FMCSA (2007d)]. The annual per power unit operational cost for firms with multiple power units was thus $297 ($297 × 1.1) for Option 3.

In addition to the productivity impacts, each carrier would incur one-time costs for training in the requirements of the new rule. To estimate the training cost, we used information from Agency personnel who participated in previous HOS retraining efforts to determine that each driver would need to take a one-time 2-hour training course to ensure compliance with the new rule provisions. As described in Chapter 6 of the RIA, we used a loaded average hourly rate of $23.96 (wages plus fringe benefits) for the industry. The 2-hour training course thus resulted in a cost of approximately $48 per driver.

Carriers would incur additional one-time costs for software reprogramming and other transition costs. As discussed in the RIA, reprogramming and other transition costs were estimated using information obtained from the HOS listening sessions conducted in various locations in early 2010. Based on information from these sessions, we assumed that the total one-time training, reprogramming, and other transition costs were about $200 per driver (including the $48 training cost discussed above). For sole proprietorships, we again assumed one driver per power unit for a total one-time cost of $200 per power unit. We view this estimate as conservative due to the fact that many firms will not incur any programming costs. We again assumed that carriers with multiple units have 1.1 drivers per power unit, for a total one-time cost of $220 per power unit [FMCSA (2007d)]. These one-time costs for sole proprietorships and multiple power unit firms are shown below in Exhibit 7-3.

To estimate the first-year costs per-power unit for affected firms, the annual and one-time costs for Option 3 were summed as shown in Exhibit 7-3. This calculation resulted in a total first-year

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[39] In this analysis, we consider sole proprietorships separately due to the fact that these firms tend to have low revenues and are thus impacted by the proposed rule differently than larger firms. We have assumed that sole proprietorships have one power unit, but their defining characteristic is their average revenues and not the number of power units they have.

cost to sole proprietorships of $470 per power unit in the first year, and a total first-year cost to firms with multiple power units of $517 per power unit.

Exhibit 7-3. First-year Costs to Affected Firms per Power Unit for Option 3

Type of Cost	Cost per Power Unit (Sole Proprietorship) [a]	Cost per Power Unit (Multiple Power Unit Firm) [a]
Annual Operating Cost (A)	$270	$297
One Time Training, Reprogramming, and Other Costs (B)	$200	$220
Total First Year Cost (A + B)	**$470**	**$517**

[a] FMCSA analysis

Next, we compared the estimated first-year costs to the average revenue for sole proprietorships and multiple power unit firms for Option 3 (shown in Exhibits 7-4). As noted earlier, average revenues for different sized firms were taken from 2007 Economic Census data.[40] For Option 3, the first year costs of the rule changes would be equal to 0.44 percent of average revenue for sole proprietorships, and 0.32 percent of average revenue for multiple unit carriers. Thus, when looking only at first year costs, the new HOS rule is not expected to have a significant impact on the average sole proprietorship or firm with multiple power units. Because of variability in both the first-year costs and the average revenues to which they are compared, however, the impact on firms would vary. It is thus likely that the impact of the first year costs would be higher for some carriers, rising to a level that could be considered significant.

Exhibit 7-4. Impact of First-year Costs on Affected Firms for Option 3 (as a Percent of Average Revenue)

Type of Cost	Sole Proprietorships	Multiple Power Unit Firms
First Year Cost Per Power Unit (A)[a]	$470	$517
Annual Revenue Per Power Unit (B)[b]	$107,657	$160,000
First Year Cost Impact as a Percentage of Annual Revenue (A / B)	0.44%	0.32%

[a] FMCSA analysis
[b] 2007 Economic Census data

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[40] To be conservative in assessing potential impacts, the revenues per power unit are based only upon for-hire firms (that is, those in Truck Transportation). As shown in Exhibit 7-2, drivers make up only a small fraction of the labor force in other industries, which underlines the point that transportation is a small part of their operations. When the Agency has looked at the impact on private carriers in relation to their revenue in the past, the percentage impact of costs to private carriers as a share of revenue have been generally been an order of magnitude smaller than the impacts on for-hire trucking firms.

7.4.2. Annual Burden on Affected Small Entities

To analyze the annual burden on affected small entities for Option 3, we amortized the one-time costs throughout a 10-year period, assuming a 7 percent discount rate. As shown in Exhibit 7-5 for Option 3, the sum of the annual operating costs and the amortized one-time costs resulted in an annual burden of $297 per year during 10 years for sole proprietorships, and an annual burden of $326 per year during 10 years for firms with multiple power units.

Next, we compared the annual burden to the average annual revenues of affected firms. As shown in Exhibit 7-5, the annual costs of Option 3 are 0.28 percent of average annual revenue for sole proprietorships, and 0.20 percent of average revenue for carriers with multiple power units. These percentages fall below what the Agency views as a reasonable threshold for a significant impact. However, as mentioned above, the impact may vary across carriers. Therefore, the annual impact of the regulations on some affected carriers may be significant in relation to their revenue.

Exhibit 7-5. Annual Impact of Costs on Firms during 10 Years for Option 3

Type of Cost	Sole Proprietorships	Multiple Power Unit Firms
Annual Cost per Power Unit (One Time Costs Amortized across 10 Years) (A) [a]	$297	$326
Annual Revenue per Power Unit (B) [b]	$107,657	$160,000
Annual Cost Impact as a Percentage of Annual Revenue (A / B)	0.28%	0.20%

[a] FMCSA analysis
[b] 2007 Economic Census data

7.4.3. Discussion of the Impact on Affected Small Entities

The analysis of the impact of the HOS rule on small entities shows that, while it is unlikely for the rule to have a significant impact on most small entities, FMCSA cannot certify that there would be no significant impacts. For a typical firm, the first-year costs of the final rule are below 1 percent of revenues, as are the average annual costs when spread across 10 years.

However, projecting the distribution of impacts across carriers, few of which fit the definition of typical, is made more difficult by the variability in both costs and revenues. The new HOS rule is designed to rein in the most extreme patterns of work while leaving more moderate operations largely unchanged. As a result, we project a substantial majority of the costs of the rule to fall on the sixth of the industry currently logging the most hours per week. Thus, most carriers are likely to be almost unaffected, while a minority could experience productivity impacts — and hence costs — well above the industry average.

Average revenues presumably range widely as well, meaning that the ratio of costs to revenues is difficult to characterize. Because greater work intensities are likely to generate greater revenues, though, the impacts and revenues per power unit are likely to be positively correlated: the carriers for which productivity is curtailed the most and which could incur the greatest costs may, therefore, be likely to have unusually large revenues per power unit as well. These heavily affected carriers could still be likely to face costs that exceed the threshold used to define significant impacts.

7.5. A description of the projected reporting, recordkeeping, and other compliance requirements of the rule, including an estimate of the classes of small entities which will be subject to the requirement and the type of professional skills necessary for the preparation of the report or record.

The rule does not change recordkeeping or reporting requirements. Drivers are required, by current rules, to keep RODS that document their daily and weekly on-duty and driving time, and submit these RODS to their employing motor carrier on a bi-weekly basis. This rule would not change or add to this recordkeeping requirement for drivers or carriers. Drivers in all segments of the industry, including independent owner-operators, are well accustomed to complying with these recordkeeping and reporting requirements, and no additional professional skill above those skills that drivers already possess would be necessary for preparing these reports. All small entities within the industry would be subject to these rules. The type and classes of these small entities are described in the previous section of this analysis.

7.6. A description of any significant alternatives to the rule which minimize any significant impact on small entities.

The Agency did not identify any significant alternatives to the rule that could lessen the burden on small entities without compromising its goals. This rule is targeted at preventing driver fatigue, and the Agency is unaware of any alternative to restricting driver work that the Agency has authority to implement that would address driver fatigue. This rule impacts motor carrier productivity proportional to the number of drivers a motor carrier employs and the intensity of the schedules that motor carrier’s drivers work. It is not obvious that productivity losses would be greater for small entities than for larger firms. To the extent that drivers working for a small entity work more intense schedules, that entity may experience greater productivity losses than a carrier whose drivers work less intensely on a daily and weekly basis. However, there appears to be no alternative available to the Agency that would limit driver fatigue while allowing more work. To improve public safety, all drivers, regardless of the size of the carrier they work for, must work within reasonable limits.

The recordkeeping and reporting burdens related to this rule would also affect entities proportional to the number of drivers they employ, and therefore does not disproportionately affect small motor carriers in any way. As noted above, drivers in all segments of the industry, working for entities of all sizes, are accustomed to compiling and submitting RODS on a regular basis. This rule would therefore not place an undue recordkeeping or reporting burden on smaller entities.

8. Changes in the Analysis of HOS Options from the NPRM to the Final Rule

This chapter presents the changes in analysis of the HOS options between the RIAs of the NPRM and of this Final Rule. There are two distinct categories of changes that result in different estimates of the costs and benefits of the HOS options between the NPRM and the Final Rule:

- Changes to the options, some of which change the cost/benefit calculations for all of the options; and
- Refinements to the benefit analyses, which change the estimated benefits, and thus the estimated net benefits, for each of the options.

The changes that fall into these two categories are discussed below, followed by a description of how they affect the estimated costs and benefits.

8.1 CHANGES TO THE OPTIONS

In response to comments received on the NPRM and new research, FMCSA has made several changes to the HOS options considered in the NPRM. The details on why these changes have been made are covered in Section I (Overview) of the preamble.

- Dropping the 13-hour limit on on-duty time between breaks of at least 10 hours, but keeping the provision requiring at least a 30-minute break part-way through long days.
- Shortening the 2-night restart window from two periods including midnight and 6:00 a.m. to two periods including 1:00 a.m. through 5:00 a.m.
- Changing the break requirements to require a break of 30 minutes (or more) within the past 8 hours of continuous work, rather than 7, in order to continue driving.
- Dropping the provision that would have allowed two 16-hour driving windows per week.

Only the first two of these changes affect the cost/benefit calculations. The other two do not change the cost/benefit calculations because the analyses for the NPRM were not sensitive to the particular provisions involved: the effects of breaks were considered to be subsumed within the effect of the daily limit on duty hours, and the use of a 16-hour driving window was not modeled due to uncertainty about how and how much it would be used and the small expected magnitude of its effects.

8.2 CHANGES IN COSTS AND BENEFITS DUE TO DROPPING THE 13-HOUR LIMIT ON ON-DUTY TIME

Dropping the provision that drivers can work no more than 13 hours out of their 14-hour driving window, but keeping the requirement of a break of at least 30 minutes to continue driving in a long workday, reduces both the costs and benefits of Options 2 and 3. For simplicity, the break and the on-duty limit in Option 4 were treated as having no incremental effect beyond the impacts of the 9-hour driving limit. In the analysis, the 30-minute break provision (like the daily on-duty limit) is assumed to affect only drivers who work more than 13 hours in a shift. The others, who are clearly not pushing the limits very hard, are assumed to be either not driving after the 8th hour, or already taking a break that would satisfy the requirement, or could shift their work slightly to accommodate a qualifying break. The impacts of the break requirement in isolation, which requires 30 minutes off-duty within the 14-hour window, is estimated to have half as much impact as the 13-hour duty limit by itself. For example, as described in some detail in Section 3.2, drivers in the high intensity category are assumed to lose an eighth of an hour of work per day that they use at least part of the 14th hour if they must take a 30-minute break. Similarly, drivers in the very high intensity category are assumed to lose a quarter of an hour per affected day, and those in the extreme category are assumed to lose a full half-hour of work per affected day. However, because the break provision overlaps with the driving limit and the weekly on-duty limit, the net effect of the break provision (and the net effect of the change from the 13-hour daily on-duty to the 30-minute break provision) is considerably reduced. Exhibit 8-1 compares the weighted productivity impacts and daily work hours lost as estimated for this Final Rule (due to the 30-minute break provision) with those as estimated in the NPRM (due to the 13-hour daily on-duty restriction). For the affected driver groups, the productivity impact is smaller under the provisions of this Final Rule than under the provisions of the NPRM.

Exhibit 8-1. Comparison of the Productivity Impacts of the 13th Hour Work Restriction and the 30-minute Break Provision

Driver Group	Weighted Productivity Impact – 30-Minute Break Provision	Weighted Productivity Impact – 13-hour Restriction	Daily Work hours Lost – 30-Minute Break Provision	Daily Work hours Lost – 13-hour Restriction
Moderate	~0%	~0%	0.00	0.00
High	0.019%	0.038%	0.05	0.11
Very High	0.072%	0.144%	0.38	0.75
Extreme	0.173%	0.345%	1.80	3.60

The benefits of the 30-minute break provision are assessed conservatively (that is, in a way that avoids overstating its benefits). We assumed the breaks to provide benefits only by reducing cumulative on-duty hours and limiting the chances for long driving days; no additional benefits are counted for the refreshing or "resetting" effect breaks are often thought to have on drivers who have grown fatigued during the course of a long, continuous drive. Counting that additional effect (which was found to cut total risk roughly in half after a break of 30 minutes), at least temporarily, would undoubtedly add further to the benefits as calculated in this analysis. Comparisons of the changes in safety and health benefits between the Final Rule and the NPRM, including the impacts of the dropping the 13-hour limit on on-duty time, are presented in Exhibits 8-3 and 8-4.

8.3 CHANGES IN COSTS AND BENEFITS DUE TO SHORTENED OVERNIGHT WINDOWS FOR THE 2-NIGHT RESTART PROVISION

To add flexibility for drivers who are not dedicated nighttime drivers, but who sometimes run past midnight or need to start somewhat before dawn, FMCSA has reduced the size of the 2 consecutive core nighttime windows that drivers would need to include in a break to restart their multiday tallies of cumulative on-duty hours. This revised window was chosen only after a review of the science behind the original provision, to be sure that it would still serve the purpose of providing 2 consecutive nighttime periods of rest including the "window of circadian low" when restorative sleep is generally easiest to obtain. Applying the same method to the same data used to estimate average impacts on hard-working drivers, FMCSA found that this modified provision would have a slightly smaller average effect on weekly work hours for the very high and extreme intensity drivers: they would lose 0.5 hour per week on average rather than 0.7 hour (including both the night drivers and the more common daytime drivers who would be unaffected). These calculations are described in Appendix E.

As with the analysis of the break provision, the 2-night restart provision's benefits are assessed conservatively, to avoid overstating them: slightly less weekly work is assumed to mean slightly more sleep, and slightly less cumulative fatigue. No special estimate is made, however, of the extra benefits of fatigue reduction for dedicated night drivers is made (despite their presumably lower sleep quality and quantity). Comparisons of the changes in safety and health benefits between the Final Rule and the NPRM, including the impacts of the shortened overnight window for the 2-night restart provision, are presented later in this chapter in Exhibits 8-3 and 8-4.

8.4 SUMMARY OF CHANGES TO COSTS OF THE HOS OPTIONS

Exhibit 8-2 compares the costs of the Final Rule with the costs of the NPRM, broken down by the three effects that the rule provisions have on driver productivity. The costs due to reductions in daily driving time increased between the Final Rule and the NPRM for Option 2, but remain unchanged for Option 4. Costs due to the restart provision increase slightly for Options 2 and 3 (due to reduced overlap with the limits on daily on-duty time), but decrease slightly for Option 4. As shown in the calculations of total costs in Exhibit 8-2, the total costs of the rule decrease slightly for each of the three HOS options.

Exhibit 8-2. Comparison of the Costs of Operational Changes for Hours-of-service Options (Millions 2008$)

Cost Category	Option 2 – Final Rule (10 Hour Option)	Option 2 – NPRM (10 Hour Option)	Option 3 – Final Rule (11 Hour Option)	Option 3 – NPRM (11 Hour Option)	Option 4 – Final Rule (9 Hour Option)	Option 4 – NPRM (9 Hour Option)
Reduction in Daily Work Hours (30-minute Break Requirement and/or 13-hour on-duty limit)	$90	$190	$90	$190	–	–
Reduction in Daily Driving Hours	$630	$590	–	–	$2,110	$2,110
Reductions Due to Restart Provisions	$230	$210	$330	$290	$130	$150
Total Costs*	**$960**	**$990**	**$430**	**$480**	**$2,240**	**$2,265**

Note: Totals do not add due to rounding.
* These costs do not include the $40 million in reprogramming costs, which remains unchanged.

8.5 REFINEMENTS TO THE BENEFITS ANALYSIS

In response to comments and its own review of the analysis of safety benefits, FMCSA has made two minor refinements to its benefits analysis of the HOS options. First, the safety benefits of reductions in cumulative fatigue are being estimated using a finer-grained function. The analysis for the NPRM counted changes in cumulative fatigue due to long hours of work in the past week in 1-hour increments: 61 hours was counted as more fatiguing that 60, and 60 was counted as more fatiguing than 59, but no distinctions were made within individual hours. To improve the precision of the analysis, and to minimize any possible overstatement of the benefits, the function used to calculate cumulative fatigue impacts now considers weekly work hours in 0.1-hour increments. We estimate that this change pulls down the estimates of benefits and net benefits by about $70 million (assuming the central estimate), which is a generally a few percent of the estimated total benefits. Because this change affects all of the options to about the same extent, it has no real effect on the relative rankings of the options. A comparison of the changes in safety benefits between the Final Rule and the NPRM, including the use of a finer-grained function for estimating reductions in cumulative fatigue, is presented in Exhibit 8-3.

Second, FMCSA has also refined its estimate of the value of reducing crash damages per hour of effort reallocated from one driver to another. Conceptually, the benefits of shifting excessive working or driving hours makes use of an estimate of the crash damages per hour, calculated by dividing the total damages from all LH crashes per year by the total number of LH hours. For the NPRM, the number of hours used in this calculation did not distinguish between driving hours and working hours. As a result, the estimated crash damages per driving hour were understated slightly, and the estimated crash damages per hour on duty were overstated slightly. For the analysis of this Final Rule, the estimated damages per hour of driving are being raised from $10.33 per hour to $11.49 per hour, and the estimated damages per hour on duty are being lowered from $10.33 per hour to $8.95 per hour. On balance, this change lowers the calculated total (and net) benefits by about $40 million (under the central estimate). Because this refinement affects all of the options equally, it has no effect on their relative ranking. A comparison of the changes in safety benefits between the Final Rule and the NPRM, including the refinement of the estimate of the value of reducing crash damages per hour, is presented in Exhibit 8-3.

8.6 SUMMARY OF CHANGES TO BENEFITS OF THE HOS OPTIONS

Exhibit 8-3 compares the safety benefits of the Final Rule with the safety benefits of the NPRM, broken down by the two effects that the rule provisions have on reduced crashes. The benefits due to reductions in driving time increased between the Final Rule and the NPRM for Options 2 and 4, but decreased for Option 3. The benefits due to reduced work time decreased for all three options. As shown in the calculations of total costs in Exhibit 8-3, the safety benefits of the rule decrease by at least $100 million for each of the three HOS options.

Exhibit 8-4 compares the health benefits of the Final Rule with the health benefits of the NPRM for each of the assumed baseline levels of sleep. The benefits for the low sleep scenario decreased between the Final Rule and the NPRM for all three options. The benefits for the medium sleep scenario also decreased slightly for all three options. The benefits of the high sleep scenario increased significantly for Option 2, which resulted in the health benefits changing from negative to positive. The benefits also increased slightly for Options 3 and 4.

Exhibit 8-3. Comparison of Safety Benefits for HOS Options (13 Percent Baseline Fatigue Risk) (Millions 2008$)

Cost Category	Option 2 – Final Rule	Option 2 – NPRM	Option 3 – Final Rule	Option 3 – NPRM	Option 4 – Final Rule	Option 4 – NPRM
Safety Benefits from Reduced Driving Time	$210	$190	$10	$20	$550	$490
Safety Benefits from Reduced Work Time	$390	$540	$270	$410	$590	$740
Total	$600	$730	$280	$430	$1,130	$1,230

Note: Totals do not add due to rounding.

Exhibit 8-4. Comparison of Health Benefits for HOS Options (Millions 2008$)

Cost Category	Option 2 – Final Rule	Option 2 – NPRM	Option 3 – Final Rule	Option 3 – NPRM	Option 4 – Final Rule	Option 4 – NPRM
Low Sleep	$1,430	$1,480	$1,120	$1,190	$1,960	$1,990
Medium Sleep	$670	$690	$620	$650	$650	$660
High Sleep	$88	-$105	$120	$100	-$660	-$670

Exhibit 8-5 sums the safety and health benefits to compare the total benefits of the Final Rule with the total benefits of the NPRM for each of the three baseline sleep scenarios and a 13 percent baseline level of fatigue involvement. For each of the baseline sleep scenarios, the total benefits decreased slightly (generally between $100 and $200 million) from the NPRM to the Final Rule for each of the HOS options.

Exhibit 8-5. Comparison of the Total Benefits of the HOS Options (13 Percent Baseline Fatigue Risk) (Millions 2008$)

Cost Category	Option 2 – Final Rule	Option 2 – NPRM	Option 3 – Final Rule	Option 3 – NPRM	Option 4 – Final Rule	Option 4 – NPRM
Low Sleep	$2,030	$2,210	$1,400	$1,620	$3,100	$3,220
Medium Sleep	$1,270	$1,420	$900	$1,080	$1,790	$1,890
High Sleep	$510	$620	$400	$530	$480	$560

8.7 SUMMARY OF CHANGES TO NET BENEFITS OF THE HOS OPTIONS

Exhibit 8-6 presents a comparison of the net benefits of the Final Rule with the net benefits of the NPRM for each of the three baseline sleep scenarios and a 13 percent baseline level of fatigue involvement. For each of the baseline sleep scenarios, the net benefits decreased slightly from the NPRM to the Final Rule for each of the HOS options. The largest decreases in net benefits between the NPRM and the Final Rule were for the low sleep scenarios for Option 2 ($150 million) and Option 3 ($170 million). For the medium sleep scenario, the net benefits of the HOS options decreased by $120 million (Option 2), $130 million (Option 3), and $80 million (Option 4) from the NPRM to the Final Rule. For the high sleep scenario, the decreases in net benefits from the NPRM to the Final Rule are less than $100 million for all three HOS options.

Exhibit 8-6. Comparison of the Net Benefits of the Hours-of-service Options (13 Percent Baseline Fatigue Risk) (Millions 2008$)

Cost Category	Option 2 – Final Rule	Option 2 – NPRM	Option 3 – Final Rule	Option 3 – NPRM	Option 4 – Final Rule	Option 4 – NPRM
Low Sleep	$1,030	$1,170	$930	$1,100	$810	$900
Medium Sleep	$270	$380	$430	$560	-$500	-$420
High Sleep	-$490	-$410	-$60	$10	-$1,810	-$1,750

Exhibit 8-7 compares the difference in net benefits of the HOS options between the Final Rule and the NPRM. As shown in the exhibit, the net benefits of the HOS options relative to each other are also very similar between the Final Rule and the NPRM. For example, for the medium sleep scenario, the net benefits of Option 3 are $160 million ($430 million - $270 million) greater than the net benefits of Option 2 for the Final Rule, as compared to $170 million ($560 million - $390 million) for the NPRM. This change – from $170 to $160 million – is of very minor significance. Similarly, under the low sleep scenario, for the final rule, the net benefits of Option 3 are $100 million lower than the net benefits of Option 2, where they were $80 million lower for the NPRM.

Exhibit 8-7. Comparison of the Difference in Net Benefits of the Hours-of-service Options (13 Percent Baseline Fatigue Risk) (Millions 2008$)

Cost Category	Option 3 minus Option 2 – Final Rule	Option 3 minus Option 2 – NPRM	Option 4 minus Option 2 – Final Rule	Option 4 minus Option 2 – NPRM
Low Sleep	-$100	-$80	-$220	-$270
Medium Sleep	$160	$170	-$770	-$810
High Sleep	$430	$420	-$1,320	-$1,340

8.8 SUMMARY OF CHANGES TO HEATH BENEFITS

As discussed in Chapter 5, FMCSA revised its methodology for calculating health benefits between the NPRM and Final Rule in response to comments. This revision recognizes that mortality benefits appear in the near term and values them using the full VSL instead of the average loss of VSLYs. Exhibits 8-8 through 8-10 present estimates of health benefits, total benefits, and net benefits using the NPRM methodology and the Final Rule methodology (assuming 7 percent discounting) for calculating health benefits.

Exhibit 8-8. Comparison of Health Benefits of the HOS Options (7 Percent Discounting for Health Benefits using Final Rule Methodology) (Millions 2008$)

Cost Category	Option 2 – NPRM Methodology	Option 2 – Final Rule Methodology	Option 3 – NPRM Methodology	Option 3 – Final Rule Methodology	Option 4 – NPRM Methodology	Option 4 – Final Rule Methodology
Low Sleep	$1,430	$810	$1,120	$630	$1,960	$1,100
Medium Sleep	$670	$380	$620	$350	$650	$370
High Sleep	$88	-$50	$120	$70	-$660	-$370

Exhibit 8-9. Comparison of the Total Benefits of the HOS Options (7 Percent Discounting for Health Benefits using Final Rule Methodology, 13 Percent Baseline Fatigue Risk) (Millions 2008$)

Cost Category	Option 2 – NPRM Methodology	Option 2 – Final Rule Methodology	Option 3 – NPRM Methodology	Option 3 – Final Rule Methodology	Option 4 – NPRM Methodology	Option 4 – Final Rule Methodology
Low Sleep	$2,030	$1,410	$1,400	$910	$3,100	$2,240
Medium Sleep	$1,270	$980	$900	$630	$1,790	$1,500
High Sleep	$510	$550	$400	$350	$480	$770

Exhibit 8-10. Comparison of the Net Benefits of the HOS Options (7 Percent Discounting for Health Benefits using Final Rule Methodology, 13 Percent Baseline Fatigue Risk) (Millions 2008$)

Cost Category	Option 2 – NPRM Methodology	Option 2 – Final Rule Methodology	Option 3 – NPRM Methodology	Option 3 – Final Rule Methodology	Option 4 – NPRM Methodology	Option 4 – Final Rule Methodology
Low Sleep	$1,030	$400	$930	$440	$810	-$50
Medium Sleep	$270	-$20	$430	$160	-$500	-$790
High Sleep	-$490	-$450	-$60	-$120	-$1,810	-$1,520

9. References

Abrams, C., Schultz, T., & Wylie C.D., "Commercial Motor Vehicle Driver Fatigue and Alertness Study and Countermeasures Survey: Alertness and Countermeasures Survey," 1997. Available in the docket: FMCSA-2004-19608-2005.

Akerstedt, T., "Sleepiness as a Consequence of Shift Work," *Sleep*, Vol. 11, No. 1, Feb. 1988, pp. 17-34.

Akerstedt, T., Kecklund, G., & Knutsson, A., "Manifest Sleepiness and the Spectral Content of the EEG During Shift Work" *Sleep,* Vol. 14, No. 3, June 1991, pp. 221-225.

Akerstedt, T., & Levi, L., "Circadian Rhythms in the Secretion of Cortisol, Adrenaline and Noradrenaline," *European Journal of Clinical Investigation*, Vol. 8, No. 2, April 1978, pp. 57-58.

Amagai, Y., Ishikawa, S., Gotoh, T., Doi, Y., Kayaba, K., Nakamura, Y., and Kajii, E."Sleep duration and mortality in Japan: the Jichi Medical School Cohort Study." Journal of Epidemiology. Vol. 14, No. 4, July 2004, pp. 124-8. Available in the docket: FMCSA-2004-19608-3955.

Balkin, T., Thome, D., Sing, H., Thomas, M., Redmond, D., Wesensten, N., Williams, J., Hall, S., & Belenky, G., "Effects of Sleep Schedules on Commercial Motor Vehicle Driver Performance," FMCSA, Washington, D.C., 2000. Available in the docket: FMCSA-2004-19608-2007.

Belman, D. L., University of Michigan Trucking Industry Program (UMTIP) Driver Surveys, 1997-1999. University of Michigan Institute for Social Research.

Blanco, M., Hanowski, R. J., Olson, R. L., Morgan, J. F., Soccolich, S. A., Wu, S-C., Guo, F, "The Impact of Driving, Non-Driving Work, and Rest Breaks on Driving Performance in Commercial Motor Vehicle Operations," The Center for Truck and Bus Safety, Virginia Tech Transportation Institute. Available in the docket: FMCSA-2004-19608-27612.

Bonnet, M.H., & Arand, D.L., "We are Chronically Sleep Deprived," *Sleep*, Vol. 18, No. 10, 1995, pp. 908-911. Abstract available in the docket: FMCSA-2004-19608-0088.

Bureau of Labor Statistics, "American Time Use Survey, Census Code 9130, Drivers/Sales Workers and Truck Drivers." Accessed November 10, 2010 from: http://www.bls.gov/tus/.

Bureau of Transportation Statistics (Research and Innovative Technology Administration, DOT) & U.S. Census Bureau, "2007 Economic Census: Transportation: 2007 Commodity Flow Survey," April 2010. Available in the docket: FMCSA-2004-19608-4024.

Campbell, K., Oak Ridge National Laboratory, letter report to R. Craft, FMCSA, Comparing GES and LTCCS Preliminary (December 22) LTCCS File, March 11, 2005.

Campbell, K.L., "Estimates of the Prevalence and Risk of Fatigue in Fatal Accidents Involving Medium and Heavy Trucks," Letter Report to FMCSA, February 25, 2005. Available in the docket: FMCSA-2004-19608-2115.

Campbell, K. L., "Evidence of Fatigue and the Circadian Rhythm in the Accident Experience," FHWA Symposium on Truck/Bus Driver Fatigue, 1988. Available in the docket: FMCSA-1997-2350-0787.

Cappuccio, F.P., D'Elia, L., Strazzullo, P., & Miller, M.A. "Sleep Duration and All-cause Mortality: A Systematic Review and Meta-Analysis of Prospective Studies," *Sleep*, Vol. 33, No. 5, 2010, pp. 585-592.

Di Milia, L. & Mummery, K., "The Association Between Job Related Factors, Short Sleep and Obesity," *Industrial Health*, Vol. 47, 2009, pp. 363-8. Available in docket: FMCSA-2004-19608-3967.

Dinges, D.F., & Kribbs, N.B., "Performing While Sleepy: Effects of Experimentally Induced Sleepiness," In T. Monk, (Ed.), *Sleep, Sleepiness and Performance,* New York: John Wiley & Sons, 1991. Available in the docket: FMCSA 1997-2350-0790

Eddy, D.R. & Hursh, S.R., "Fatigue Avoidance Scheduling Tool: Phase I SBIR Final Report," NTI Inc., 2001. Accessed November 17, 11, 2010, from: http://www.fatiguescience.com/products/fast.

Federal Motor Carrier Safety Administration, "2007 Hours of Service Study," (2007 FMCSA Field Survey), 2007b. Available in the docket: FMCSA-2004-19608-2538.

Federal Motor Carrier Safety Administration, "Analyses of Fatigue-Related Large Truck Crashes, the Assignment of Critical Reason, and Other Variables Using the Large Truck Crash Causation Study," 2008c. Available in the docket: FMCSA-2004-19608-3481.

Federal Motor Carrier Safety Administration, "Environmental Assessment for Hours of Service (HOS) Rule," In Appendix A, Table A-1 - Hours of Service Truck Vehicle Miles of Travel Mode Shift Analysis, December 2002b. Available in docket: FMCSA-1997-2350-23303.

Federal Motor Carrier Safety Administration, "FMCSA HOS Field Survey: Implementation and Use of the April 2003 Hours-of-Service Regulations," (2005 FMCSA Field Survey), 2005b. Available in the docket: FMCSA-2004-19608-2090.

Federal Motor Carrier Safety Administration, "Hours of Service of Drivers; Driver Rest and Sleep for Safe Operations; Final Rule," 68 FR 22456, April 28, 2003. Available in docket: FMCSA-97-2350-23305.

Federal Motor Carrier Safety Administration, "Hours of Service of Drivers; Final Rule," 70 FR 49978, August 25, 2005a. Available in docket: FMCSA-2004-19608-2114.

Federal Motor Carrier Safety Administration, “Hours of Service of Drivers; Final Rule,” 73 FR 69567, November 19, 2008a. Available in docket: FMCSA-2004-19608-3508.

Federal Motor Carrier Safety Administration, “Hours of Service of Drivers; Interim Final Rule,” 72 FR 71247, December 17, 2007a. Available in docket: FMCSA-2004-19608-2578.

Federal Motor Carrier Safety Administration, “Regulatory Evaluation of the Fees for the Unified Carrier Registration Plan,” February 19, 2010. Available in the docket: FMCSA-2009-0231-0181.

Federal Motor Carrier Safety Administration, “Regulatory Impact Analysis for Hours of Service Options,” 2008b. Available in the docket: FMCSA-2004-19608-3510.1.

Federal Motor Carrier Safety Administration, “Regulatory Impact Analysis and Small Business Analysis for Hours of Service Options,” 2002a. Available in docket: FMCSA-1997-2350-23302.

Federal Motor Carrier Safety Administration, “SAFER Data,” 2007c. Accessed August 5, 2010, from: from: http://safer.fmcsa.dot.gov/.

Federal Motor Carrier Safety Administration, “SAFER Data: Average Drivers per Power Unit for TL Firms,” 2007d. Accessed August 6, 2010, from: http://safer.fmcsa.dot.gov/.

Ferrie, J., Shipley, M., Cappuccio, F., Brunner, E., Miller, M., Kumari, M., & Marmot, M., “A Prospective Study of Change in Sleep Duration: Associations with Mortality in the Whitehall II Cohort,” *Sleep*, Vol. 30, No. 12, 2007, pp. 1659-1666. Available in the docket: FMCSA-2004-19608-3969.

FleetSeek, “Private Fleet Directory 2007-2008,” 2008. Accessed August 5, 2010, from: http://fleetowner.com/fleetseek/pfd_new.htm.

Folkard, S. & Lombardi, D., “Modeling the Impact of the Components of Long Work Hours on Injuries and “Accidents,” *American Journal of Industrial Medicine*, Vol. 49 No. 11, November 2006, pp. 953-963. Available in the docket: FMCSA-2004-19608-4019.

Frith, W.J., “A Case Control Study of Heavy Vehicle Drivers’ Working Time and Safety,” *Proceedings of the 17th AARB (Australian Road Research Board) Conference Part 5*, August 15-19, 1994, pp. 17-30. Available in the docket: FMCSA-1997-2350-0521.

Gillberg, M., & Akerstedt, T. “Sleep Loss and Performance: No “Safe” Duration of a Monotonous Task,” *Physiology and Behavior*, Vol. 64, No. 5, July 1998, pp. 599-604.

Gold, D.R, Rogacz, S, Bock, N, Tosteson, T.D, Baum, T.M, Speizer, F.E, & Czeisler, C.A, “Rotating Shift Work, Sleep and Accidents Related to Sleepiness in Hospital Nurses,” *American Journal of Public Health,* Vol. 82, No. 7, July 1992, pp. 1011-1014.

Hanowski, R.J., Hickman, J.S., Fumero, M.C., Olson, R.L., & Dingus, T.A., “The Sleep of Commercial Vehicle Drivers under the 2003 Hours-of-Service Regulations, *Accident,* *Analysis and Prevention*, Vol. 39, No. 6, November 2007, pp. 1140-1145. Available in the docket: FMCSA-2004-19608-3977.

Hanowski, R.J., Hickman, J.S., Olson, R.L., & Bocanegra, J., “Evaluating the 2003 Revised Hours-of-Service Regulations for Truck Drivers: The Impact of Time on Task on Critical Incident Risk,” *Accident, Analysis and Prevention*, Vol. 41, No. 2, March 2009, pp. 268-275. Available in the docket: FMCSA-2004-19608-3978.

Harris, W., “Fatigue, Circadian Rhythm and Truck Accidents,” In R. Mackie (Ed.), *Vigilance: Theory, Operational Performance and Physiological Correlates* (pp.133-146). New York: Plenum Press, 1977.

Jones, I.S., & Stein, H.S., “Effect of Driver Hours of Service on Tractor-Trailer Crash Involvement,” Insurance Institute for Highway Safety, September 1987. Available in the docket: FMCSA-1997-2350-0521.

Jones-Lee, M.W., “Valuing International Safety Externalities: Does the ‘Golden Rule’ Apply?,” *Journal of Risk and Uncertainty*, Vol. 29, No. 3, 2004, pp. 277-287.

Jovanis, P.P., Wu, K-F, & Chen, C., “Hours of Service and Driver Fatigue: Driver Characteristics Research,” May, 2011. Available in the Docket: FMCSA-2004-19608-27614.

Jovanis, P.P., Park S.-W., Chen, K.-Y., Gross, F., & Mukherjee, A. “Factors Affecting Motor Carrier Crash Risk: Final Report,” September 30, 2005. Available in the docket: FMCSA-2004-19608-3322.1.

Kaneko, T., & Jovanis, P.P., “Multiday Driving Patterns and Motor Carrier Accident Risk: A Disaggregate Analysis,” *Accident Analysis and Prevention*, Vol. 24, No. 5, 1992, pp. 437-456.

Katzmarzyk, P.T., Church, T.S., Craig , C.L., & Bouchard, C., “Sitting Time and Mortality from All Causes, Cardiovascular Disease, and Cancer,” *Medicine and Science in Sports and Exercise*, Vol. 41, No. 5, May 2009, pp. 998-1005. Available in the docket: FMCSA-2004-19608-4001.

Lin, T.D., Jovanis, P.P., & Yang, C.Z., “Modeling the Safety of Truck Driver Service Hours Using Time-Dependent Logistic Regression,” *Transportation Research Record*, No. 1407, 1993, pp. 1-10. Available in the docket: FMCSA-2004-19608-0069.

Lin, T.D., Jovanis, P.P., & Yang, C.Z., “Time of Day Models of Motor Carrier Accident Risk,” *Transportation Research Record*, No. 1467, 1994, pp. 1-8. Available in the docket: FMCSA-1997-2350-0521.

Mackie, R.R., & Miller, J.C., “Effects of Irregular Schedules and Physical Work on Commercial Driver Fatigue and Performance,” *Human Factors in Transport Research*. London: Academic Press Inc., 1980.

Martin, B.C., Church, T.S., Bonnell, R., Ben-Joseph, R. & Borgstadt, T., "The Impact of Overweight and Obesity on the Direct Medical Costs of Truck Drivers," *Journal of Occupational and Environmental Medicine*, Vol. 51, February 2009, pp. 180-184. Available in the docket: FMCSA-2004-19608-4004.

Matteson, A., Jarossi, L., & Woodrooffe, J., "Trucks Involved in Fatal Accidents Factbook 2005," 2008. Accessed August 6, 2010, from: http://deepblue.lib.umich.edu/bitstream/2027.42/58054/1/48532%20A48.pdf

Mitler, M.M.; Carskadon, M.A.; Czeisler, C.A.; Dement, W.C.; Dinges, D.F.; & Graeber, R.C., "Castastrophes, Sleep, and Public Policy-Consensus Report," *Sleep*, Vol. 11, No. 1, 1988, pp. 100-109. Available in the docket: FMCSA-1997-2350-0782.

Mokdad, A.H., Ford, E.S., Bowman, B.A., Dietz, W.H., Vinicor, F., Bales, V.S., & Marks, J.S., "Prevalence of Obesity, Diabetes, and Obesity-Related Health Risk Factors, 2001," *Journal of the American Medical Association,* Vol. 289, No. 1, 2003, pp. 76-79. Available in docket: FMCSA-2004-19608-4016.

O'Neill, T.R., Krueger, G.P., Van Hemel, S.B. & McGowan, A.L., "Effects of Operating Practices on Commercial Driver Alertness," 1999. Available in the docket: FMCSA-2004-19608-0071.

Park, S.W., Mukherjee, A, Gross, F., & Jovanis, P.P., "Safety Implications of Multi-Day Driving Schedules for Truck Drivers: Comparison of Field Experiments and Crash Data Analysis," Transportation Research Board Annual Meeting, 2005. Available in the docket: FMCSA-2004-19608-1998.

Pilutti, T., and Ulsoy, A.G., "Identification of Driver State for Lane-Keeping Tasks: Experimental Results." *Proceedings of the American Control Conference*, Albuquerque, NM, June 1997.

Saccomanno, F.F., Yu, M., & Shortreed, J.H., "Effect of Driver Fatigue on Truck Accident Rates," In L.J. Sucharov (Ed.), *Urban Transport and the Environment for the 21st Century*, 1995, pp. 439-446.

Social Security Administration, Actuarial Tables, 2006. Accessed July 27, 2010, from: http://www.ssa.gov/OACT/STATS/table4c6.html.

Stein, A. C., "Detecting Fatigued Drivers with Vehicle Simulators," *Driver Impairment, Driver Fatigue and Driving Simulation*, L. Hartley, ed., Taylor & Francis, Bristol, PA, 1995, pp. 133-150.

Szabat, J., Deputy Assistant Secretary for Transportation Policy, to Lindy Knapp, Acting General Counsel, "Treatment of the Economic Value of a Statistical Life in Departmental Analyses – 2009 Annual Revision," March 18, 2009. Retrieved July 27, 2010, from: http://ostpxweb.dot.gov/policy/reports/vsl%20guidance%20031809%20a.pdf.

Tamakoshi, A., & Ohno, Y. "Self-Reported Sleep Duration as a Predictor of All-Cause Mortality: Results from the JACC Study, Japan," *Sleep*. Vol. 27, No. 1, 2004, pp. 51-54. Available in the docket: FMCSA-2004-19608-4018.

Toth, G., Radja, G., Thiriez, K., & Carra, J., "Large Truck Crash Causation Study in the United States," 2006. Accessed August 6, 2010, from: http://www.nhtsa.gov/DOT/NHTSA/NRD/Articles/ESV/PDF/18/Files/18ESV-000252.pdf.

U. S. Census Bureau, "2007 Economic Census: Tables 2.1 to 2.11," 2007a. Retrieved August 6, 2010, from: http://www.census.gov/svsd/www/services/sas/sas_data/48/2007_NAICS48.xls. Available in the docket: FMCSA-2004-19608-4022.

U. S. Census Bureau, "2007 Nonemployer Statistics," 2007b. Retrieved August 6, 2010, from: http://factfinder.census.gov/servlet/IBQTable?_bm=y&-ds_name=NS0700A1&-NAICS2007=484&-ib_type=NAICS2007&-_industry=484&-_lang=en. Available in the docket: FMCSA-2004-19608-4024.

U. S. Census Bureau, "Table H2. Households, by Type, Age of Members, Region of Residence, and Age of Householde: 2010," 2010. Retrieved November 16, 2010, from: http://www.census.gov/population/socdemo/hh-fam/cps2010/tabH2-all.xls.

United States Court of Appeals, District of Columbia Circuit, "Owner-Operator Independent Drivers Assoc., Inc. v. FMCSA," 494 F.3d 188, 2007. Accessed August 5, 2010, from: http://www.olblueusa.org/images/7-24-07-US-Court-of-Appeals.pdf.

United States Court of Appeals, District of Columbia Circuit, "Public Citizen *et al.* v. FMCSA," 374 F.3d 1209, 2004. Accessed August 4, 2010 from: http://ftp.resource.org/courts.gov/c/F3/374/374.F3d.1209.03-1165.html.

Van Cauter, E., & Knutson, K., "Sleep and the Epidemic of Obesity in Children and Adults," *European Journal of Endocrinology*, Vol. 159, 2008, pp. S59-66. Available in docket: FMCSA-2004-19608-3991.

Wiegand, D. M., Hanowski, R. J., & McDonald, S. E., "'Commercial Drivers' Health: A Naturalistic Study of Body Mass Index, Fatigue, and Involvement in Safety-Critical Events," *Traffic Injury Prevention*, Vol. 10, No. 6, December 2009, pp. 573-579. Available in the docket: FMCSA-2004-19608-3994.

Williamson, A.M.; Feyer, A.M.; & Friswell, R., "The Impact of Work Practices on Fatigue in Long Distance Truck Drivers," *Accident Analysis and Prevention*, Vol. 28, No. 6, 1996, pp. 709-719. Available in the docket: FMCSA-2004-19608-2077.

Zaloshnja, E., & Miller, T., "Unit Costs of Medium/Heavy Truck Crashes," March 13, 2007. Available in docket: FMCSA 2004-19608-3995.