Appendix A – DATA AND CALCULATIONS FOR INDUSTRY PROFILE

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APPENDIX A

DATA AND CALCULATIONS FOR INDUSTRY PROFILE

This appendix presents additional information on the data sources and the calculations used in the industry profile chapter (Chapter 2).

1. Trends in Vehicle Miles Traveled, Ton-Miles, and Revenue

Data on activity in 2002 and 2007 were taken from the following sources[1]:

- American Trucking Associations (ATA), *Trucking Activity Report, Historic Data Base* (ATA (2008b)) — index of truckload vehicle miles traveled (VMT). (We used the seasonally adjusted indices for June.)
- Federal Highway Administration, *Highway Statistics* for 2002 and 2008 (FHWA (2002) and FHWA (2008)) — Table VM-1 (provides VMT of combination trucks (tractor-trailers) on rural roads).
- U.S. Census Bureau and Bureau of Transportation Statistics, *Economic Census: Transportation: Commodity Flow Survey* for 2002 and 2007 (CFS (2002) and CFS (2007)) — Table 1a **(**provides ton-miles of truck freight).
- U.S. Census Bureau, *2007 Economic Census* (EC (2007)), Transportation and Warehousing—long-distance trucking revenue, adjusted for price increases using Bureau of Economic Analysis (BEA) price indices for sector output.

The following exhibit shows values for 2002 and 2007 and annual growth rates for the industry from 2002 to 2007.

Exhibit 1. Annual Growth Rates – 2002 to 2007

	ATA (2008b) VMT Index	**FHWA (2002) and FHWA (2008) VMT**	**CFS (2002) and CFS (2007) For-hire ton-miles**	**EC (2007) Revenue**
2002	99.9	87.54 billion	959.6 billion	$129.1 billion
2007	92.5	82.89 billion	1,055.6 billion	$151.6 billion
Growth rate	-1.5 percent	-1.1 percent	1.9 percent	3.3 percent

2007 nominal revenue was $180.2 billion. This revenue figure was adjusted back to 2002 prices with the BEA price indices for truck transportation found in Industry Economic Accounts, gross domestic product (GDP) by Industry Accounts. The calculation is as follows:

- 2002 index: 104.2

[1] For a complete list of the sources used in Appendix A, see section 9, References, beginning on page A-10.

- 2007 index: 123.8
- $180.2 billion x 104.2 / 123.8 = $151.6 billion

2. Less-Than-Truckload Percentage of For-Hire VMT

The estimate of less-than-truckload (LTL) percentage of VMT is based on the 1992 *Census of Transportation: Truck Inventory and Use Survey* (TIUS (1992)), the 1997 and 2002 *Economic Census: Vehicle Inventory and Use Survey* (VIUS (1997) and VIUS (2002)), and revenue data from the Economic Censuses (EC) for 1997, 2002, and 2007 (EC (1997) and EC (2002)).

The TIUS/VIUS data show LTL and truckload long-distance for-hire VMT. The EC data show revenue for long-distance, for-hire service for both LTL and truckload (1992 EC data were not used, because truckload and LTL data were not reported separately). The relevant percentages are shown in Exhibit 2.

Exhibit 2. Less-Than-Truckload and Truckload VMT and Revenue Percentages

	VMT		Revenue	
	Truckload	**LTL**	**Truckload**	**LTL**
1992	81.8%	18.2%		
1997	75.7%	24.3%	67.2%	32.8%
2002	84.2%	15.8%	70.0%	30.0%
2007			68.9%	31.1%

The VMT data show percentages in 1992 and 2002 in roughly the 16 – 18 percent range with a spike in LTL share in 1997. The revenue data, however, show a consistent LTL percentage in a narrow range. Based on the revenue data, therefore, we treated the spike in LTL percentage in 1997 as an anomaly, and we estimated the LTL share of VMT at 17.0 percent.

3. Number of Truckload Firms by Fleet Size

Estimating the number of truckload firms by fleet size was a somewhat complex process. We developed an estimate of approximately 75,000 long-haul, for-hire firms in mid-2008 using the following data sources:

- U.S. Census Bureau, data from EC (2002) and *Statistics of U.S. Businesses: 2005* (analysis was done before EC (2007) data were available).
- FleetSeek, *National Motor Carrier Directory* (NMCD (2008)), 2008 edition (2007 or later data).
- American Trucking Associations, *ATA Fleet Directory,* 2008 edition (2005-2007 for-hire data).
- John Siebert, *OOIDA Analysis of the 2002 VIUS to Determine the Owner-Operator Role in the American Trucking Industry* (Siebert (2005)), from the Owner Operator Independent Drivers Association (OOIDA) (analysis of 2002 VIUS data and other data from OOIDA).

The greatest challenge to estimating the population of long-haul, for-hire firms is the problem of estimating the number of firms with one-to-five tractors. (If a firm has no tractors, we assume it is in short-haul operation.) These are the owner-operators; some of them have employees, the great preponderance of them does not. While the EC data on firms with employees seem reliable, there are questions about how to interpret the EC data on non-employee firms.

The starting point for the estimate is the EC (2002) data on long-haul carriers with employees.[2] The relevant data are those for the types of carriers shown in Exhibit 3.

Exhibit 3. Long-Haul Firms in EC (2002)

Type of Carrier	NAICS Code	Number of Firms
General freight	48412	29,220
Household goods	4842102	2,970
Specialized freight	48423	10,706
Total		42,896
Adjusted for short-time firms		37,525

General freight and household goods are self-explanatory. Specialized freight is cargo moving on flatbeds, in tank trailers, or in refrigerated trailers.[3]

4. Question of Firms in Operation Less Than 1 Year

Before using these data as the basis for our estimates, we had to consider the issue of firms in operation for less than a year. The total includes 10,743 firms that were in operation for less than 1 year, or 25 percent of all the firms reported for 2002. The comparable fraction for the 1997 EC is 23 percent, which suggests some stability in the relative size of this group. (The 2005 data do not include this figure.) Of the firms with less than 1 year in 2002, 74 percent were in the general-freight category, where one would expect a higher rate of turnover. Market opportunities are potentially more numerous for a small firm with ordinary vans, and capital needed to enter the market is higher for carriage that requires refrigerated vans or tank trailers.

If we included all of the short-time firms in our base number, the result would be an over-estimate of the number of firms in operation at any given time. It was clear that a downward adjustment must be made. For this analysis, we assumed that the average short-time firm is in operation for 6 months; therefore, we reduced the total by one-half of 10,743 (42,896 – (10,743 / 2)). These are the firms with employees in 2002. In order to complete the estimate, we had to adjust for growth to 2005 and then add carriers without employees.

We can bring the estimate of employee firms up to 2005 by using data from the *Statistics of U.S. Businesses: 2005*.[4] We cannot use the 2005 data directly because they are not strictly

[2] U.S. Census Bureau, EC (2002), Transportation and Warehousing — Subject Series, Table 4.
[3] This terminology is not directly equivalent to commonly used terms in the industry. In the business, specialized freight usually refers only to flatbed movements; and traffic in tank trailers is referred to as bulk.
[4] U.S. Census Bureau, Statistics of U.S. Businesses: 2005: Retrieved August 4, 2010, from: http://www.census.gov/epcd/susb/2005/us/US48.HTM#N484.

comparable to the 2002 data. The 2005 report does not separate household goods carriers between short and long haul, and it does not include a number for the short-time firms. Therefore, we must obtain a growth factor by comparing the sum of long-haul general-freight and specialized-freight firms in 2005 with the same value for 2002. This procedure is shown in Exhibit 4.

Exhibit 4. Firms with Employees

	2002	**2005**
General freight	29,220	30,365
Specialized freight	10,706	10,213
Totals	39,926	40,578
Growth factor	1.016 (40,578 / 39,926)	
2005 estimate Growth factor applied to 2002 adjusted for short-time firms	38,137 (1.016 x 37,525)	

5. Owner-Operators

The next step was to add an estimate of firms without employees, i.e., owner-operators. We note that some, not many, owner-operators have employees, so the estimate for firms with employees already includes some owner-operators. We must also note that the great majority of owner-operators in long-haul carriage are not truly independent firms. They work under lease contracts with larger firms. Typically, the owner-operator provides his tractor and trailer and his labor in return for an agreed mileage rate. In effect, such leased drivers are part of the larger firm's labor force.

The principal data on owner-operators and non-employee firms come from two different sources: Siebert (2005) and the EC data on Non-Employer Statistics for 2002 and 2005. At first glance, these two sources lead to very different results.

An estimate of approximately 80,000 owner-operators owning one to five tractors can be derived from the Siebert (2005) analysis. The Siebert (2005) data indicate that about 30 percent of OOIDA's members are independent firms, not working under lease.[5] In the absence of any firm basis for believing that this percentage would be different for the universe of owner-operators, we use the OOIDA percentage for an estimate. This leads to 24,000 independent owner-operators, both long-haul and short-haul.

The Non-Employer Statistics, on the other hand, appear to lead to a much higher estimate. The Non-Employer Statistics show 276,987 firms for long-haul, general freight in 2005. Also, these data show 47,708 such firms in specialized trucking but do not break specialized service between long-haul and short-haul. If we add 184,278 firms reported as short-haul, we reach 508,973, or about 510,000 non-employer firms in 2005, as shown in Exhibit 5.

[5] Based on an unpublished OOIDA 2006 Member Profile Survey; data supplied in e-mail from John Siebert, May 22, 2008.

Exhibit 5. Non-Employer Firms from 2005 Non-Employer Statistics

General freight long-haul	*276,987*
General freight short-haul	*184,278*
Specialized freight	*47,708*
Total	***508,973***

The Siebert (2005) data show about 500,000 power units owned by owner-operators in 2002. These estimates are consistent with one another. Earlier data also show a large number of owner-operators of all types. In a study referenced in the 2003 RIA, University of Michigan Professor Francine Lafontaine estimated that there were 320,000 owner-operators.

A further analysis of VIUS data reveals, however, that the 500,000 power units shown in the Siebert (2005) analysis include a large number of vehicles of less than 10,000 pounds. When we exclude these vehicles from the count, the power units owned by owner-operators drop to about 325,000 vehicles. In light of this, it is reasonable to make a similar downward adjustment for the non-employer firms to 325,000.

But we have to make a further adjustment to reach a number for long-haul firms. The Non-Employer Statistics are drawn from Federal income-tax returns in which the absence of employees is clear. A trucking firm without employees must be an owner-operator (although some owner-operators have employees). In the Non-Employer Statistics, however, self-designation becomes a problem in the distinction between short and long-haul. In the instructions for Schedule C of IRS Form 1040, filers are asked to select type of business from a long list of types of business. General-freight short-haul and long-haul are two of the choices listed, but there is no guidance as to definition. Specialized freight is the only other choice for a trucking firm, but there is no distinction between short and long haul.

There is every reason to believe that a large number of filers who identified themselves as long-distance are, in fact, short-haul, i.e., have average lengths of haul under 100 miles. Intuitively, it is clear that many drivers would think of a run to a different city 75 to 100 miles away, for example, as a long-distance move. It is also clear that a large number of owner-operators own only straight trucks. Our analysis of VIUS shows that 95 percent of for-hire straight trucks are in short-haul service, and 38 percent of for-hire tractors are in short-haul service. Thus, virtually all owner-operators that have no tractors are short-haul; and a significant fraction of those that do have tractors are also short-haul. The Siebert (2005) data indicate that over half of owner-operators own no tractors. Setting aside specialized freight, the Non-Employer Statistics show approximately 40.0 percent of firms are short-haul and 60.0 percent long-haul. In light of the distribution of trucks and tractors between long and short-haul, it is difficult to accept this pattern.

We may use the percentages of for-hire tractors and straight trucks that are in long-haul service to estimate the percentage of non-employer firms that are in long-haul service. From the Siebert (2005) data, we can extract an estimate of the percentages of straight trucks and tractors owned by owner-operators: respectively 50.4 and 49.6 percent of owner-operators' power units. By applying these percentages to the percentages of straight trucks and tractors in long-haul service, we obtain 33.5 percent, or one-third ([0.052 x 0.504] + [0.622 x 0.496] = 0.335).

We previously adjusted the non-employer estimate down to 325,000 firms with power units of 10,000 pounds or more. With our estimate of 30 percent of owner-operators as independent firms, this yields 97,500 independent, non-employer owner-operators, 32,500 of whom (one-third) are in long-haul operation. Adding this to our estimate of 38,000 firms with employees takes us to an estimate of 70,500 long-haul firms in 2005.

Exhibit 6 shows the chain of calculations that leads to the estimate of non-employer firms.

Exhibit 6. Non-Employer Firms

Total from Statistics of U.S. Businesses, 2005	510,000
Exclusion of vehicles <10,000 lbs.	325,000
Independent owner-operators	97,500 (0.3 x 325,000)
Independent owner-operatorss in long-haul service	32,500 (⅓ x 97,500)

Note: The final figure of 32,500 does not include owner-operators with employees; these are in the EC data for firms with employees.

6. Updating to 2008

The above estimates gave us 38,000 firms with employees in 2005 and 32,500 non-employee firms. From EC (1997), EC (2002), and the Statistics of U.S. Businesses, 2005, we can calculate growth rates for both groups of firms from 1997 to 2005. We can apply those growth rates to bring the 2005 estimates up to mid-2008. To obtain the growth rates, we must compare the sum of long-haul general freight and specialized freight (not including household goods) in 1997 and 2005 for firms with employees, since the 2005 data do not include household goods. We do not adjust these numbers for short-time firms, because the 2005 data do not allow for this adjustment. For non-employee firms, we simply compare the reported numbers of general-freight, long-haul firms in 1997 and 2005. When applying the growth rate, we use the power of 2.5, because we are going from the end of 2005 to the middle of 2008. We may take this as an approximate estimate of 75,000 long-haul, for-hire firms operating in mid-2008 (as shown in Exhibit 7).

Exhibit 7. Estimate of Firms Operating in 2008

	1997	**2005**	**Mid-2008**	**Growth rate**
Employee GF + specialized	35,278	40,578		1.6%
Non-employee	184,132	276,987		5.2%
Employee estimate		38,000	39,538 ($38,000 \times 1.016^{2.5}$)	
Non-employee estimate		32,500	36,891 ($32,500 \times 1.052^{2.5}$)	
Total		**70,500**	**76,429**	

7. Size Distribution

For size distribution of for-hire firms, we may take the data from the commercial directories: FleetSeek's *National Motor Carrier Directory* (NMCD (2008)) and the *ATA Fleet Directory*. Both of these directories capture significant fractions of the employee firms reported in EC (2002) — about 25 percent for the *ATA Fleet Directory* and 44 percent for NMCD (2008). This is enough data for their size distributions to be reliable, especially for firms with more than five tractors, those that are larger than the owner-operators. Further, the distributions reported in the two directories are sufficiently close to each other to be mutually corroborating. We see this in the following table showing distribution for firms with more than five tractors.

Exhibit 8. Size Distribution of For-Hire Firms

	NMCD (2008)		ATA Fleet Directory	
Tractors	**Firms**	**Percentage**	**Firms**	**Percentage**
6–10	8,223	40.1%	6,073	35.6%
11–20	5,286	25.7%	4,859	28.5%
21–40	3,378	16.5%	2,867	16.8%
41–75	1,799	8.8%	1,518	8.9%
76–150	1,003	4.9%	929	5.4%
151–500	644	3.1%	600	3.5%
>500	197	1.0%	221	1.3%
Total	**20,530**		**17,067**	

Since the NMCD (2008) data base is the larger, 44,000 firms (including those with 1–5 tractors) against 25,000 in the *ATA Fleet Directory*, we use it as the basis for estimating size distribution. The 44,000 firms in the NMCD (2008) data are 44 percent of the approximately 100,000 firms reported in EC (2002), long-haul and short-haul — without adjustment for short-time firms. With a sample this large, and with the support of the ATA data, we can accept the NMCD (2008) percentages as reliable for firms with six or more tractors. The distribution for all firms in the NMCD (2008) data, including the one-to-five class is shown in Exhibit 9.

Exhibit 9. Size Distribution for All Firms from NMCD (2008) Data

NMCD		
Tractors	**Companies**	**Percent**
1–5	23,710	53.6%
6–10	8,223	18.6%
11–20	5,286	11.9%
21–40	3,378	7.6%
41–75	1,799	4.1%
76–150	1,003	2.3%
151–500	644	1.5%
>500	197	0.4%
Total	**44,240**	

The FleetSeek staff makes an effort to exclude owner-operators from their directory, so we can take the NMCD-reported firms with one-to-five tractors as employer firms and, thus, firms accounted for in the EC. Our key assumption is that FleetSeek captures something close to the universe of firms with six or more tractors. Therefore, we need to estimate the number of long-haul firms with employees in the one-to-five class and add the non-employee firms to get a total for this class.

We do this by first reducing the NMCD (2008) number of 23,710 for the one-to-five class to its long-haul component by applying the percentage of EC firms in long-haul service, or 43 percent (including short-time firms). This brings us to 10,206 firms in this size class. We then use, as an expansion factor, 0.61, the ratio of the NMCD (2008) population to the EC population of employer firms (adjusted for short-time firms) and obtain 16,626 employer firms in this size class. To this we add our estimate of 36,891 non-employer long-haul firms for a total of 53,517 long-haul firms in the one-to-five class. Exhibit 10 shows the chain of calculations.

Exhibit 10. Calculations for the Number of Firms with Employees Having One to Five Tractors

NMCD firms in 1–5	*23,710*
NMCD long-haul firms in 1–5	*10,206* *(0.43 x 23,710)*
EC employer firms in 1–5	*16,626* *(10,206 / 0.61)*
All firms in 1–5	*53,517* *(16,626 + 36,891)*

All firms with more than five tractors are taken to be employer firms. Therefore, we subtract the 16,626 employer firms in the one-to-five class from our estimate of 39,538 long-haul employer firms and obtain 22,912 firms with more than five tractors. We distribute these firms over the higher size classes using the NMCD (2008) percentages shown above. The result is shown in Exhibit 11.

Exhibit 11. Distribution of Firms by Class Size

Tractors	**Companies**	***Percentage***
1–5	53,517	*70.0%*
6–10	9,177	*12.0%*
11–20	5,899	*7.7%*
21–40	3,770	*4.9%*
41–75	2,008	*2.6%*
76–150	1,119	*1.5%*
151–-500	719	*0.9%*
>500	220	*0.3%*
Total	***76,429***	***100.0%***

8. Average Hours Worked per Week

The estimate of approximately 53 hours worked per week is based on Exhibit 2-6 in the 2008 HOS Regulatory Impact Analysis, which is reproduced below.

Exhibit 2-6
Average Weekly Hours and Days Worked

	2005 FMCSA Field Survey	**Schneider**
On-duty hours/8 days	59	62
Days worked per week	5.6	5.9

Data sources were the 2005 FMCSA Field Survey and data on work times supplied by Schneider National. Both sources give us hours worked in 8 days—62 hours for Schneider drivers, 59 hours for field-survey drivers.[6] Some intermediate steps are required to convert these numbers to hours per week. The average of the Field Survey and Schneider numbers is 60.5 per 8 days. We scale this back to obtain hours per week as follows:

60.5 x 7/8 = 52.9

[6] For both data sources, we discarded all drivers with fewer than 50 hours of work in 8 days on the grounds that they were not driving full-time in the period covered.

9. References

American Trucking Associations, "ATA Fleet Directory," 2008. Accessed August 12, 2010, from: http://www.atabusinesssolutions.com/p-60-ata-fleet-directory.aspx.

American Trucking Associations, "Trucking Activity Report, Historic Data Base," July 2008b. Accessed August 12, 2010, from: http://www.atabusinesssolutions.com/p-24-ata-trucking-activity-report-trac.aspx.

Federal Highway Administration, "Highway Statistics 2002." Accessed August 12, 2010, from: http://www.fhwa.dot.gov/policy/ohim/hs02/index.htm. Table VM-1 — Annual Vehicle Distance Traveled in Miles and Related Data: By Highway Category and Vehicle Type Highway Administration (November 2003) is at: http://www.fhwa.dot.gov/policy/ohim/hs02/pdf/vm1.pdf

Federal Highway Administration, "Highway Statistics 2008." Accessed August 12, 2010, from: http://www.fhwa.dot.gov/policyinformation/statistics/2008/. Table VM-1 — Annual Vehicle Distance Traveled in Miles and Related Data: By Highway Category and Vehicle Type Highway Administration (December 2009) is at: http://www.fhwa.dot.gov/policyinformation/statistics/2008/vm1.cfm.

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

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

FleetSeek, "National Motor Carrier Directory," 2008. Accessed August 12, 2010, from: http://fleetowner.com/fleetseek/nmcd_new.htm.

Internal Revenue Service, "2009 Instructions for Schedule C: Profit or Loss from Business." Retrieved August 26, 2010 from: http://www.irs.gov/pub/irs-pdf/i1040sc.pdf

Siebert, John, "OOIDA Analysis of the 2002 VIUS to Determine the Owner-Operator Role in the American Trucking Industry," *OOIDA Foundation*, April 2005.

Siebert, John, OOIDA 2006 Member Profile Survey (Unpublished), data supplied in e-mail, May 22, 2008.

U.S. Census Bureau, "Census of Transportation: Truck Inventory and Use Survey," 1992. Accessed August 12, 2010, from: http://www.census.gov/svsd/www/92vehinv.html.

U.S. Census Bureau, "1997 Economic Census," 1997. Accessed August 12, 2010, from: http://factfinder.census.gov/servlet/DatasetMainPageServlet?_program=ECN&_tabId=ECN3&_submenuId=datasets_4&_lang=en&sess_on.

U.S. Census Bureau, "1997 Economic Census: Vehicle Inventory and Use Survey," 1997. Accessed August 12, 2010, from: http://www.census.gov/svsd/www/97vehinv.html.

U.S. Census Bureau, “2002 Economic Census,” 2002. Accessed August 12, 2010, from: http://factfinder.census.gov/servlet/DatasetMainPageServlet?_program=ECN&_tabId=ECN2&_submenuId=datasets_4&_lang=en&sess_on.

[1] U.S. Census Bureau, “2002 Economic Statistics: Non-Employer Statistics Transportation and Warehousing United States.” Accessed September 8, 2010, from: http://www.census.gov/epcd/nonemployer/2002/us/US000_48.HTM

U.S. Census Bureau, “2002 Economic Census – Transportation and Warehousing: Vehicle Inventory and Use Survey, Final Reports, Geographic ‘Area Series,” 2002. Accessed August 12, 2010, from: http://www.census.gov/prod/www/abs/ec2002trans-vius-geo.html.

U.S. Census Bureau, “Non-Employer Statistics, 2005: Transportation and Warehousing: United States,” 2005. Accessed August 12, 2010, from: http://www.census.gov/epcd/nonemployer/2005/us/US000_48.HTM.

U.S. Census Bureau, “Statistics of U.S. Businesses: 2005,” 2005. Accessed August 12, 2010, from: http://www.census.gov/epcd/susb/2005/us/US--.HTM.

U.S. Census Bureau, “2007 Economic Census,” 2007. Accessed August 12, 2010, from: http://factfinder.census.gov/servlet/DatasetMainPageServlet?_program=ECN&_tabId=ECN1&_submenuId=datasets_4&_lang=en&sess_on.

U.S. Census Bureau, “Non-Employer Statistics, 2007: Transportation and Warehousing: United States” Accessed August 26, 2010, from: http://www.census.gov/epcd/nonemployer/latest/us/US000_48.HTM

U.S. Census Bureau and Bureau of Transportation Statistics, “2002 Economic Census: Transportation: 2002 Commodity Flow Survey,” December 2003. Accessed August 12, 2010, from: http://www.census.gov/prod/ec02/02tcf-usp.pdf.

U.S. Census Bureau and Bureau of Transportation Statistics, “2007 Economic Census: Transportation: 2007 Commodity Flow Survey,” April 2010. Accessed August 12, 2010, from: http://www.census.gov/prod/2010pubs/ec07tcf-us.pdf. Available in the docket: FMCSA-2004-19608-4024.

Appendix B – Literature Review on the Health Impacts of the Hours of Service Rule Changes

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Appendix B – Literature Review on the Health Impacts of the Hours of Service Rule Changes

Introduction

PURPOSE OF THE REVIEW

As many as 4.5 million Americans work as commercial motor vehicle (CMV) drivers. While there is no such thing as a “typical” driver, drivers can be considered to belong to categories based on the type of vehicle driven, the schedule on which they drive, and the type of load they typically carry. Drivers differ in whether they work under a union arrangement, or as independent contractors or employees of non-unionized companies. The majority of drivers are male; 2009 Bureau of Labor Statistics (BLS) data record that in the category of “Driver/sales workers and truck drivers” 5.2 percent of workers are female, and women make up 5.9 percent of “Motor vehicle operators, other” (BLS 2009). We have a general sense of the age distribution of drivers (*see* Exhibit 1) from a database of 64,000 drivers complied by RoadReady:

Exhibit 1. Age Distribution of Drivers

Age Category	# in Category	% in Category
20-29	9242	14%
30-39	18986	29%
40-49	20525	32%
50-59	12310	19%
60-69	3252	5%
70-79	280	0%
80-89	14	0%

This type of work is characterized by long hours, both per day and per week. It is sedentary and can involve sitting for 8 to 14 hours per day. Drivers often experience short sleep or intermittent sleep schedules. These factors lead to a concern over such health issues as obesity, obstructive sleep apnea, and chronic fatigue.

The Centers for Disease Control and Prevention (CDC) MMWR Morbidity and Mortality Weekly Report for February 2008 (CDC 2008) lists the following as being associated with insufficient rest: mental distress; depression; anxiety; **obesity**; hypertension; diabetes; high cholesterol; cigarette smoking; physical inactivity; heavy drinking; and cardiovascular disease. The National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK 2010) links obesity/overweight to: diabetes; coronary heart disease; high blood cholesterol; stroke; hypertension; gallbladder disease; osteoarthritis; sleep apnea and other breathing problems; and some forms of cancer.

There is evidence to support the perception that drivers are more likely to be overweight or obese than are members of the general population (Exhibit 2). Both of the driver populations listed in the Exhibit are LTL drivers and, therefore, unlikely to work extreme hours although likely to drive at night.

The purpose of this review is to provide information to support proposed revisions of hours of work regulations, with the goal of increasing both driver safety and the safety of the public, as well as to maximize the health and well-being of CMV drivers. To conduct this review we reviewed the literature on health impacts and conditions among all persons; we did not restrict the reviewed literature to that directly concerned with CMV drivers because drivers are no less likely than other people to be subject to health impacts caused by lack of sleep and sedentary lifestyle.

Exhibit 2. Obesity Prevalence Among Three Populations

FMCSA Fatigue Management Survey – 2,128 drivers (Dinges et al. 2005)		**Impact on medical costs of truck drivers – 2,950 drivers (Martin et al. 2009)**		**National all adult males (Flegal et al. 2010)**	
BMI	*% drivers*	*BMI*	*% drivers*	*BMI*	*% adult males*
<25	10.3	18.5-24.9	13	<25	27.7
25-29.9	39.9	25-29.9	30	25-29.9	40.1
30-34.9	26.3	≥30	55	30-34.9	17.3
35-39.9	11.3			35-39.9	10.7
40+	12.3			40+	4.2

Structure of the Chapter

This chapter is structured in two major sections. In the first section we present data from three studies of sleep and mortality from which we were able to extract data to produce a curve demonstrating the expected lost years of life based on typical hours of sleep. We discuss the implications of this model for Hours of Service regulations.

In the second section we examine research that suggests a chain of relationships between the "driver lifestyle" of long hours, protracted sitting, and moderate-to-severe sleep deprivation; obesity as a potential outcome of this lifestyle; and health problems and costs frequently linked to obesity. We present conclusions from this set of studies and we outline the need for additional evidence in this area. The studies referenced in this appendix are available in docket FMCSA-2004-19608.

Methodology

<u>**Section 1**</u>

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.

For the statistical analyses of the Phase 1 sleep-hours data in the Ferrie study, we assumed that a response of "6" means 5.5 to 6.5 hours, etc. On that basis, we fitted a normal distribution to the Phase 1 "hours of sleep" frequency distribution and obtained a mean of 6.787 hours and a standard deviation of 0.768 hours.

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.

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 5.5-6.5 hours, and so forth. This model uses Phase 1 frequency distribution 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*exph + error
Exph = expected value of hours of sleep if between from and to
Exphh = expected value of hours of sleep squared if between from and to
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 (for the full set of predicted ratios, see Section 1 below)

Section 2

For the second section of this chapter we again searched PubMed with the following limits: publication date in past 10 years, English language, human (non-animal) studies, with the following keywords or phrases: sleep; health; "long hours;" "shift work;" obesity; fatigue; "sleep deprivation;" "sedentary work;" "sedentary lifestyle;" "truck drivers;" "short sleep duration;" "increased mortality;" and "health effects." We also searched Ovid, Scopus, and Google Scholar using the phrases "short sleep duration;" "increased mortality;" and "health effects." We reviewed studies and data from FMCSA that relate to fatigue or truck driver health to identify any statistics on obesity, high blood pressure (HBP), cardiovascular disease (CVD), obstructive sleep apnea (OSA), or related topics. We reviewed reference lists in the identified studies to determine whether additional titles would be useful.

Section 1. Sleep and Mortality

The data presented in this section are taken from three large-scale, long-term studies [Amagai et al. 2004; Ferrie et al. 2007; Tamakoshi et al. 2004]. Amagai et al. followed 11,325 participants over 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].[1]

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 et al. (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 was found to show the lowest mortality risk" [Tamakoshi et al. 2004, p.51]. Exhibit 3 presents the results of the quantitative analysis of the Ferrie et al. 2007 data:

Exhibit 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

[1] 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 CI of .8 – 3 is not statistically significant; and OR of 1.2, with a CI of 1.1-1.5 is significant.

Exhibit 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
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

Mapping these values on a graph results in a U-shaped curve in which seven hours of sleep carries the lowest hazard ratio, and sleep periods of less than seven and more than seven hours show a progressively larger mortality hazard ratio.

Section 2: Driver Health Outcomes

For the population at large, researchers have spent much time and effort to understand the relationships between individual activities and habits and their possible eventual health outcomes. For example, a simple linear example of this kind is the causal relationship we now understand to exist between cigarette smoking and risk of lung cancer. We can expect these same relationships to hold true for commercial vehicle drivers, as drivers are a segment of the U.S. population and are subject to the same behavioral and genetic forces that act on non-drivers.

In reviewing possible outcomes of the “driver lifestyle” of long hours, protracted sitting, and moderate-to-severe sleep deprivation; we cannot posit a simple linear relationship between “lifestyle” and one or more health outcomes. Rather we need to view this relationship as a network of mutually-reinforcing effects that will result in varying levels of risk in terms of particular outcomes such as cardiovascular disease. Exhibit 4 reflects current thinking on how this network of relationships acts on human health:

Exhibit 4. Health habit and risk relationships

Long hours	→	Insufficient sleep
	→	Obesity
	→	Cardiovascular disease
Sedentary pattern	→	Obesity
	→	Metabolism
	→	Increased risk of mortality
Obstructive sleep apnea	→	High blood pressure
	→	Cardiovascular disease
	→	Diabetes
	→	Increased risk of mortality
Insufficient sleep	→	Obesity
	→	High blood pressure
	→	Diabetes
Obesity	→	Obstructive sleep apnea
	→	High blood pressure
	→	Cardiovascular disease
	→	Stroke
	→	Diabetes
	→	Arthritis
	→	Other disease

Long Hours and Insufficient Sleep

Artazcoz et al. (2009, p.521) looked at 7,103 salaried workers aged 16–64 in Spain to compare work hours with health-related behaviors. They categorized work hours as “less than 30 h (part-time), 30–40 (reference category), 41–50 and 51–60 h.” For men, longer work hours were associated with “shortage of sleep (aOR 1.42, 95% CI 1.09 to 1.85) and no leisure-time physical activity (aOR 2.43, 95% CI 1.64 to 3.60). Moreover, a gradient from standard working hours to 51–60 h a week was found for these six outcomes. Among women long working hours were only related to smoking and to shortage of sleep.”

Knauth (2007, p.127) conducted a literature review of “105 studies on the effects of extended daily working hours.” He produced a table of “Effects of extended shifts on duration or quality of sleep.” 13 studies cited “worse” sleep in shifts longer than 8 hours; 6 studies found no difference; eight studies found “better” sleep. He acknowledges that some of the studies had methodological problems, making a firm conclusion difficult.

LONG HOURS AND OBESITY

Di Milia and Mummery (2009, p.364) administered a survey to “804 Australian participants employed in the coal industry and 275 participants from a regional university.” “Participants were allocated into … three groups based on the mean work duration per shift; ‘short’ (M=8.72 h±0.56), ‘medium’ (M=10.95 h±0.56) and ‘long’ (M=12.60 h±0.41).” Mean Body Mass Index (BMI) was significantly higher in shift workers than in day workers (p<.001). Mean BMI (12.60 h±0.41) was also significantly higher (p<.001) higher in the group working long daily hours followed by medium working hours (10.95 h±0.56) and short working hours (8.72 h±0.56).” The authors report “the most significant predictor of obesity was long working hours (OR=2.82, CI:1.10-7.19).”

Violanti et al. (2009, p.194) looked at “atypical work hours,” including midnight shifts, among 98 police officers and a possible relationship to metabolic syndrome (a group of metabolic risk factors for coronary heart disease and type 2 diabetes; it includes abdominal obesity). They report, “Stratification on sleep duration and overtime revealed significant associations between midnight shifts and the mean number of metabolic syndrome components among officers with less sleep (p. = .013) and more overtime (p. = .007). Results suggest shorter sleep duration and more overtime combined with midnight shift work may be important contributors to the metabolic syndrome.”

LONG HOURS AND CARDIOVASCULAR DISEASE

Chen et al. (2005, p.890) report on results from the Taxi Drivers’ Health Study from Taiwan. The authors used questionnaires to assess “driving time profiles” for 1,157 drivers; long driving time was defined as “self-reported monthly driving time” divided into quartiles (≤208 hours; 210-260 hours; 261-312 hours; and 318-450 hours). They measured whole blood cell (WBC) count as “a haematological marker for increased CVD risk” as it is a sign of “systemic inflammation and haemostatic alteration.” They report “After adjusting for conventional CVD risk factors” and a series of demographic factors such as alcohol drinking, “long driving time was still associated with significant increases in WBC and platelets, whereas the effect on haemotocrit was diminished and became statistically non-significant.”

INSUFFICIENT SLEEP AND OBESITY

Banks and Dinges (2007, p.519) report that “laboratory studies of healthy adults subjected to sleep restriction have found adverse effects on endocrine functions, metabolic and inflammatory responses, suggesting that sleep restriction produces physiological consequences that may be unhealthy.”

Schoenborn and Adams (2008, p.1) reported on “the association between sleep and selected health risk behaviors using data from the 2004-2006 [National Health Interview Survey] NHIS.” They state, “Direction of causality cannot be determined with cross-sectional survey data. However, identifying health risk behaviors among adults with varying sleep durations can provide useful information on possible clustering of behaviors that are known to be associated with unfavorable health outcomes." Regarding sleep and obesity, "Overall, about one in four adults were obese (25%), based on self-reported height and weight. Adults who slept less than 6 hours had the highest rate of obesity (33%) and adults who slept 7 to 8 hours had the lowest (22%) … This pattern was found for both men and women and across all age groups and most race/ethnicity groups studied. The association between sleep and obesity was less striking among adults aged 65 years and over than among younger adults" (p.3).

Van Cauter and Knutson (2008, p. S59) reviewed laboratory studies "indicating that sleep curtailment in young adults results in a constellation of metabolic and endocrine alterations, including decreased glucose tolerance, decreased insulin sensitivity, elevated sympathovagal balance, increased evening concentrations of cortisol, increased levels of ghrelin, decreased levels of leptin, and increased hunger and appetite." They also reviewed cross-sectional and prospective epidemiological studies showing an increased risk of weight gain in short sleepers. They conclude, "Findings from laboratory studies in young adults and epidemiological studies in both children and adults converge to suggest that partial chronic sleep restriction, an increasingly prevalent behavior in modern society, may increase the risk of weight gain and play a role in the current epidemic of obesity" (p.S64).

Patel and Hu (2008, p.643) conducted a meta-analysis based on a literature search for "all articles published between 1966 and January 2007 using the search "sleep" AND ("duration" OR "hour" OR "hours") AND ("obesity" OR "weight") in the MEDLINE database." "Thirty-six publications (31 cross-sectional, 5 prospective, and 0 experimental) were identified. Findings in both cross-sectional and cohort studies of children suggested short sleep duration is strongly and consistently associated with concurrent and future obesity. Results from adult cross-sectional analyses were more mixed with 17 of 23 studies supporting an independent association between short sleep duration and increased weight. In contrast, all three longitudinal studies in adults found a positive association between short sleep duration and future weight."

Cappuccio et al. (2008, p.1) also performed a meta-analysis, using resources in addition to MEDLINE (EMBASE, AMED, CINAHL, PsychINFO, and "manual searches without language restrictions" from 1982). "Criteria for inclusion were: report of duration of sleep as exposure, BMI as continuous outcome and prevalence of obesity as categorical outcome, number of participants, age, and gender." 36 population samples were included in the analysis, for 634,511 participants. They report "In children the pooled OR for short duration of sleep and obesity was 1.89 (1.46 to 2.43; P < 0.0001). In adults the pooled OR was 1.55 (1.43 to 1.68; P < 0.0001). There was no evidence of publication bias. In adults, the pooled ß for short sleep duration was -0.35 (-0.57 to -0.12) unit change in BMI per hour of sleep change." They state "Cross-sectional studies from around the world show a consistent increased risk of obesity amongst short sleepers in children and adults."

INSUFFICIENT SLEEP AND HIGH BLOOD PRESSURE

Gangwisch et al. (2006, p.833) looked at the possibility of increased risk of hypertension in individuals with short sleep (but without sleep disorders). They "assessed whether short sleep duration would increase the risk for hypertension incidence by conducting longitudinal analyses of the first National Health and Nutrition Examination Survey (*n*=4810) using Cox proportional hazards models and controlling for covariates." They found, "Sleep durations of ≤5 hours per night were associated with a significantly increased risk of hypertension (hazard ratio, 2.10; 95% CI, 1.58 to 2.79) in subjects between the ages of 32 and 59 years, and controlling for the potential confounding variables only partially attenuated this relationship. The increased risk continued to be significant after controlling for obesity and diabetes."

INSUFFICIENT SLEEP AND DIABETES

Hayashino et al. (2007, p.1) looked at the relationship between sleep quality and quantity and the risk of developing diabetes among "healthy workers" in Japan. "Of the 6509 participants included in the current analysis, the average age (range) and body-mass index at baseline were 38.2 (19-69) years and 22.6 kg/m^2, suggesting that the study population consisted of relatively young and lean workers" (p.3). Although they found no connection between length of sleep and diabetes, "For participants who often experienced difficulty in initiating sleep, the multivariate-adjusted hazard ratios for diabetes were 1.42 (95% CI, 1.05-1.91) in participants with a medium frequency of difficulty initiating sleep, and 1.61 (95% CI, 1.00-2.58) for those with a high frequency, with a statistically significant linear trend" (p.1).

Gottleib et al. (2005, p.863) "assessed the cross-sectional relation of usual sleep time to diabetes mellitus (DM) and [impaired glucose tolerance (IGT)] among participants in the Sleep Heart Health Study." They report that "Compared with those sleeping 7 to 8 hours per night, subjects sleeping 5 hours or less and 6 hours per night had adjusted odds ratios for DM of 2.51 (95% confidence interval, 1.57-402) and 1.66 (95% confidence interval, 1.15-2.39), respectively. Adjusted odds ratios for IGT were 1.33 (95% confidence interval, 0.83-2.15) and 1.58 (95% confidence interval, 1.15-2.18), respectively. Subjects sleeping 9 hours or more per night also had increased odds ratios for DM and IGT."

SEDENTARY PATTERN AND OBESITY

Caban et al. (2005, p.1) produced a report on obesity rates across professional categories in the United States. Their report is based on self-reported weight and height collected annually on US workers age 18 or over, from the 1986 to 1995 and the 1997 to 2002 National Health Interview Surveys. The authors used survey responses to calculate annual occupation-specific prevalence rates for obesity. They report "pooled obesity prevalence rates were highest in motor vehicle operators (31.7% in men; 31.0% in women)." "During the period from 1986 to 1995, the highest pooled obesity rates were observed for male workers employed as motor vehicle operators (19.8%) …for female workers, the highest pooled obesity rates were among motor vehicle operators (22.6%)" (p.5). "In the period from 1997 to 2002, the highest pooled obesity rates were observed for male workers employed as motor vehicle operators (31.7%) … for female workers, those employed as motor vehicle operators (31.0%)."

Mummery et al. (2005, p.91) looked at "occupational sitting time" and BMI among 1,579 full-time Australian workers. Within the sample, mean sitting time for men was 209 minutes. The authors report "Univariate analyses showed significant associations between occupational sitting time and BMI of > or = 25 in men but not in women." "The odds ratio for BMI > or = 25 was 1.92 (CI 1.17-3.17) in men who reported sitting for >6 hours/day compared with those who sat for <45 minutes/day."

Dahl et al. (2009, p.345) report that a 10-year follow-up study beginning in 1994 was done to "examine standardized hospital treatment ratios (SHR) of lifestyle related diseases in a cohort of long haul truck drivers in Denmark compared with SHRs among other truck drivers and the working population at large." They found that "Compared to the working population at large both long haul and other drivers had a statistical significant elevated risk for being hospitalized for obesity (SHR:254, 95% CI: 127-454) and diabetes mellitus (SHR:140, 95% CI: 104-185)."

"Personal lifestyle and working conditions are supposed to be tightly interwoven in long haul truck driving, but when compared to other truck drivers this does not reflect major differences in lifestyle related diseases, with the exception of a significantly lower risk for alcohol-related diseases and a possibly higher risk for lung cancer. All truck drivers had an increased risk of hospital treatment for diseases related to excess caloric intake and lack of exercise."

Healy et al. (2008, p.661) looked at the flip side of sedentary behavior/obesity. They followed 168 participants in the Australian Diabetes, Obesity and Lifestyle study to see whether those who had more frequent breaks in their sedentary time as measured over seven consecutive days (although experiencing the same overall amount of sedentary time) would show better scores in terms of several health measures including BMI and resting blood pressure. They report, "Independent of total sedentary time and moderate-to-vigorous intensity activity time, increased breaks in sedentary time were beneficially associated with waist circumference (standardized ß = -0.16, 95% CI -0.31 to -0.02, P = 0.026), BMI (ß = -0.19, -0.35 to -0.02, P = 0.026), triglycerides (ß = -0.18, -0.34 to -0.02, P = 0.029), and 2-h plasma glucose (ß = -0.18, -0.34 to -0.02, P = 0.025)."

SEDENTARY PATTERN AND METABOLISM

Hamilton et al. (2007, p.2655) looked at sedentary time and its relationship to mortality, CV disease, Type 2 diabetes, metabolic syndrome and obesity. The authors go beyond the usual examination of levels of exercise and look at the cellular processes involved in extended sitting (as opposed to "the normally high volume of intermittent nonexercise physical activity in everyday life"). They experimented in the laboratory with "reducing normal spontaneous standing and ambulatory time" to see the effect on a protein "important for controlling plasma triglyceride catabolism, HDL cholesterol, and other metabolic risk factors." They found, "Experimentally reducing normal spontaneous standing and ambulatory time had a much greater effect on LPL regulation than adding vigorous exercise training on top of the normal level of nonexercise activity." They conclude "the average nonexercising person may become even more metabolically unfit in the coming years if they sit too much."

SEDENTARY PATTERN AND INCREASED RISK OF MORTALITY

Katzmarzyk et al. (2009, p.998) "prospectively examined sitting time and mortality in a representative sample of 17,013 Canadians 18-90 [years] of age." Subjects were followed for an average of 12 years; 1,832 deaths occurred during the period. Sitting time was characterized as "almost none of the time," "one fourth of the time," "half of the time," three fourths of the time," and "almost all of the time." The authors report, "After adjustment for potential confounders, there was a progressively higher risk of mortality across higher levels of sitting time from all causes (hazard ratios (HR): 1.00, 1.00, 1.11, 1.36, 1.54; P for trend <0.0001) and CVD (HR: 1.00, 1.01, 1.22, 1.47, 1.54; P for trend <0.0001) but not cancer." This held true independent of leisure-time activity.

OBESITY AND HEALTH OUTCOMES

Mokdad et al. (2008, p.76) reviewed data from the 2001 Behavioral Risk Factor Surveillance System (BRFSS) to look for associations between obesity and health risk factors. They defined overweight and obesity as follows: overweight – BMI 25 through 29.9; obesity – BMI 30 – 39.9; BMI 40 or higher. They report, "Overweight and obesity were significantly associated with diabetes, high blood pressure, high cholesterol, asthma, arthritis, and poor health status. Compared with adults with normal weight, adults with a BMI of 40 or higher had an odds ratio

(OR) of 7.37 (95% confidence interval [CI], 6.39-8.50) for diagnosed diabetes, 6.38 (95% CI, 5.67-7.17) for high blood pressure, 1.88 (95% CI, 1.67-2.13) for high cholesterol levels, 2.72 (95% CI, 2.38-3.12) for asthma, 4.41 (95% CI, 3.91-4.97) for arthritis, and 4.19 (95% CI, 3.68-4.76) for fair or poor health."

Lenz et al. (2009, p.641) reviewed 27 meta-analyses (international) and 15 cohort studies (German) to determine whether overweight and obesity elevate morbidity and mortality. They did not find an elevated mortality rate, but in both overweight and obese individuals the risk for certain disease-specific morbidity was elevated: "The overall mortality of overweight persons (body mass index [BMI] 25-29.9 kg/m^2) is no higher than that of persons of normal weight (BMI 18.5-24.9 kg/m^2), but their mortality from individual diseases is elevated, diminished or unchanged, depending on the particular disease." Disease-specific risk areas include cardiovascular risk, Type 2 diabetes, orthopedic complications, neoplastic diseases, asthma, renal diseases, and gastroesophageal reflux disease. The studies reviewed by Lenz et al. indicate that, "Morbidity and mortality are markedly influenced by" demographic characteristics such as age, sex, ethnic origin, and social status.

Finkelstein (2010, p. 336) presented data from the National Health Interview Survey Linked Mortality Files to estimate life expectancies by levels of weight, age, race, gender, and smoking status. Obesity levels II (BMI 35 <40) were significantly associated with the loss of 4 to 5 years of life for whites. Obesity levels III (BMI 40+) were significantly associated with the loss of 5 to 10 years across both races. Smoking status made little difference.

Grotle et al. (2008, n.p.) explored the possible relationship between obesity and osteoarthritis in the knee, hip, and hand among 1,854 Norwegians aged 24-76 years. The authors followed participants for 10 years and included 1,675 persons in the analysis. The authors defined obesity as BMI of 30 and above; osteoarthritis was self-reported. "At 10-years follow-up the incidence rates were 5.8 percent (CI 4.3-7.3) for hip OA, 7.3 percent (CI 5.7-9.0) for knee OA, and 5.6 percent (CI 4.2-7.1) for hand OA. When adjusting for age, gender, work status and leisure time activities, a high BMI (>30) was significantly associated with knee OA (OR 2.81; 95% CI 1.32-5.96), and a dose-response relationship was found for this association. Obesity was also significantly associated with hand OA (OR 2.59; 1.08-6.19), but not with hip OA (OR 1.11; 0.41-2.97). There was no statistically significant interaction effect between BMI and gender, age or any of the other confounding variables."

Obstructive Sleep Apnea and High Blood Pressure

Okada et al. (2006, p.891) studied 207 men (age 30 to 76) who had undergone health screenings. Based on polysomnography, 29 percent were considered to have sleep-disordered breathing with hypopnea. "The frequency of obesity (BMI≥25), hypertension, hypercholesterolemia, fasting blood glucose level, and HbA1c were significantly higher in patients with SDB than in normal individuals (AHI<5 times/h)." "The results … suggest that as SDB becomes severe, it becomes more closely linked to the onset of lifestyle-related illnesses, such as hypertension, hypercholesterolemia and abnormal glucose metabolism."

Obstructive Sleep Apnea and Cardiovascular Disease

Chami et al. (2008, n.p.) "assessed the relation of SDB to LV morphology and systolic function in a community based sample of middle-aged and older adults." They report "A polysomnographically derived apnea-hypopnea index (AHI) and hypoxemia index (percent of sleep time with oxyhemoglobin saturation <90%) were used to quantify SDB severity. LV mass index was significantly associated with both AHI and hypoxemia index after adjustment for age, sex, ethnicity, study site, body mass index, current and prior smoking … etc." They conclude "In a community-based cohort, SDB is associated with echocardiographic evidence of increased LV mass and reduced LV systolic function."

Mehra et al. (2006, p.910) report that for 6,441 members of the Sleep Heart Health Study, "individuals with severe sleep-disordered breathing have two-to fourfold higher odds of complex arrhythmias than those without sleep-disordered breathing even after adjustment for potential confounders."

Obstructive Sleep Apnea and Diabetes

Seicean et al. (2008, p.1001) looked for a possible association between "sleep-disordered breathing [SDB]," diabetes precursors (impaired fasting glucose – IFG and impaired glucose tolerance – IGT), and "occult diabetes" among 2,588 study participants aged 52 to 96 years. "SDB was observed in 209 non overweight and 1,036 overweight/obese participants. SDB groups had significantly higher adjusted prevalence and adjusted odds of IFG, IFG plus IGT, and occult diabetes. The adjusted odds ratio for all subjects was 1.3 (95% CI 1.1-1.6) for IFG, 1.2 (1.0-1.4) for IGT, 1.4 (1.1-2.7) for IFG plus IGT, and 1.7 (1.1-2.7) for occult diabetes." Associations held even after adjusting for age, sex, race, BMI, waist circumference. The authors conclude "The significant association … suggests the importance of SDB as a risk factor for clinically important levels of metabolic dysfunction."

Marshall et al. (2009, p.15) examined sleep apnea as an independent risk factor for diabetes. Among 295 study participants, "at baseline moderate severe OSA [obstructive sleep apnea] was associated with a univariate, but not multivariate, increased risk of diabetes (odds ration = 4.37, 95% CL = 1.12, 17.12). Longitudinally, moderate-severe OSA was a significant univariate and independent risk factor for incident diabetes (fully adjusted OR = 13.45, 95% CL = 1.59, 114.11)."

Obstructive Sleep Apnea and Increased Risk of Mortality

Marshall et al. (2008, p.1079) examined whether OSA "is an independent risk factor for all-cause mortality in a community-based sample free from clinical referral bias." "Among the 380 participants … moderate-to-severe OSA was independently associated with greater risk of all-cause mortality (fully adjusted hazard ratio [HR] = 6.24, 95% CL 2.01, 19.39) than non-OSA (*n* = 285, 22 deaths). Mild OSA (RDI 5 to <15/hr) was not an independent risk factor for higher mortality (HR = 0.47, 95% CL 0.17, 1.29)." The authors conclude, "Moderate-to-severe sleep apnea is independently associated with a large increased risk of all-cause mortality in this community-based sample."

Punjabi et al. (2009, p.1) reported on the relationship between sleep-disordered breathing and mortality among 6,441 men and women participating in the Sleep Heart Health Study and concluded, "Sleep-disordered breathing is associated with all-cause mortality and specifically that due to coronary artery disease, particularly in men aged 40-70 years with severe sleep-disordered breathing."

Costs of Negative Health Outcomes

The potential costs of negative health outcomes can be measured in two ways: the actual dollar costs of medical care and associated costs for particular health problems; or increased mortality. Below we present a brief overview of selected studies which give some idea of the range of costs that may be experienced by overweight or obese persons.

Cost of overweight or obesity

Martin et al. (2009, p. 180) conducted a study among drivers for a large national transportation logistics company; the study was a "retrospective cross sectional study design in which BMI was measured at baseline and costs were ascertained in the 1 year follow-up period. Costs and disease prevalences were compared across normal weight, overweight, and obese subjects." The study *n* was 2,950. The authors report, "Unadjusted trimmed total cost for overweight subjects ($1613) and obese subjects ($1792) were significantly higher than for normal weight subjects ($1012; P < 0.05). After multivariate adjustment, obese and overweight subjects had on average, $591 (P=0.031) and $383 (P=0.188) higher total trimmed health care cost than normal weight subjects." "Both overweight and obese individuals had higher health care costs and higher prevalence of hyperlipidemia, diabetes, and hypertension than their normal weight counterparts."

Banno et al. (2008, p.247) discuss additional expenses incurred by obese women with and without sleep apnea, compared against normal weight controls. "Obese women are heavier users of health services than normal weight controls. Obese women with [obstructive sleep apnea syndrome] OSAS use significantly more health services than obese controls." (p.247). "Physician fees, in Canadian dollars, one year before diagnosis in the OSAS cases were higher than in obese controls: $547.49 ± 34.79 vs $246.85 ± 20.88 (P < 0.0001)." "Physician visits one year before diagnosis in the OSAS cases were more frequent than in the obese controls: 13.2 ± 0.73 visits vs 7.26 ± 0.49 visits (P < 0.0001)."

Schulte et al. (2008, p.560) present an overview of the interaction between occupational hazards and obesity. In terms of cost, they cite studies that have measured "the annual direct medical and absenteeism costs in the US attributable to excess weight" as being between $175 to $2,027 for men and $588 to $2,164 for persons with BMI from 25 to over 40.

Rosekind at al. (2010, p.91) conducted a web-based anonymous survey of employees at "four US-based companies." They used the survey responses to classify employees into sleep-disturbed groups based on criteria for insomnia and insufficient sleep syndrome. They used responses from the Work Limitations Questionnaire as a basis for assessing productivity losses and costs among respondents. The authors conclude, "Fatigue-related productivity losses were estimated to cost $1967/employee annually."

Hauner (2009, p. 639) cites a report of a study on BMI and cause-specific mortality in 900,000 adults published in 2009 which "showed an average loss of 2 to 4 years of life with a BMI between 30 and 34.9 kg/m^2, and a BMI between 40 and 45 kg/m^2 shortened life by an average of 8 to 10 years."

DISCUSSION

The research cited here, along with other studies that have reached similar conclusions, supports the view that the effects of a sedentary lifestyle and insufficient sleep put individuals at risk for overweight or obesity. Overweight and obesity in turn contribute to a range of negative health effects that may be damaging by themselves, or may lead to other health problems. The policy implications of this view suggest that employment rules favoring a more active lifestyle and more adequate sleep could lead to overall health benefits.

A number of researchers have noted the need for further work to refine our understanding of the role of sleep in maintaining health. Grandner and Patel (2009, p. 146) point out that "research needs to address the role of individual differences regarding sleep duration preferences. We need to differentiate between natural (possibly healthy) short/long sleep and insufficient/overextended sleep." Similarly, "We need to conduct community-based intervention studies to assess the effect of modifying sleep times on health outcomes and mortality."

Czeisler (2009, p.249-275), in his review of current knowledge on medical and genetic differences in the effect of sleep loss on individual performance, notes these effects may be related to age, to the effects of food, drugs or pharmacological agents, work schedules, sleep disorders, family responsibilities, psychiatric disorders, or other factors. In writing about work schedules for physicians, Czeisler emphasizes the need to better understand the medical and genetic basis of individual differences, and calls for the integration of this understanding into policy-setting for work schedules and hours. Van Dongen and Belenky (2009, p.518) note "trait individual variability in vulnerability to performance impairment due to sleep loss" and they state: "Judiciously selecting or monitoring individuals in specific tasks or occupations, within legally and ethically acceptable boundaries, has the potential to improve operational performance and productivity, reduce errors and accidents, and save lives."

The Mollicone et al. (2008, p.833) study is one example of another direction for continued research – sleep scheduling to maximize sleep benefits while supporting work schedules. The authors studied 90 individuals assigned to "a range of sleep/wake scenarios with chronically reduced nocturnal sleep, augmented with a diurnal nap." They conclude "The results suggest that reductions in total daily sleep result in a near-linear accumulation of impairment regardless of whether sleep is scheduled as a consolidated nocturnal sleep period or split into a nocturnal anchor sleep period and a diurnal nap" making split sleep schedules feasible for work requiring restricted night-time sleep.

References

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.124-128. Available in the docket: FMCSA-2004-19608-3955.

Artazcoz, L., Cortés, I., Escribà-Agüir, V., Cascant, L., and Villegas, R., "Understanding the Relationship of Long Working Hours with Health Status and Health-Related Behaviours," *Journal of Epidemiology and Community Health*, Vol. 63, No. 7, July 2009, pp. 521-527. Available in the docket: FMCSA-2004-19608-3998.

Banks, S. and Dinges, D.F., "Behavioral and Physiological Consequences of Sleep Restriction," *Journal of Clinical Sleep Medicine*, Vol. 3, No. 5, August 15, 2007, pp. 519-528. Available in the docket: FMCSA-2004-19608-3957.

Banno, K., Ramsey, C., Walld, R., and Kryger, M., "Expenditure on Health Care in Obese Women With and Without Sleep Apnea," *Sleep*, Vol. 32, No. 2, May 2009, pp. 247-252. Available in the docket: FMCSA-2004-19608-3958.

Bureau of Labor Statistics, "Labor Force Statistics from the Current Population Survey (2009)." Retrieved August 18, 2010, from: http://www.bls.gov/cps/tables.htm. Available in the docket: FMCSA-2004-19608-4023.1.

Caban, A., Lee, D., Fleming, L., Gómez-Marín, O., LeBlanc, W., and Pitman, T., "Obesity in US Workers: the National Health Interview Survey, 1986 to 2002," *American Journal of Public Health*, Vol. 95, No. 9, September 2005, pp. 1614-1622. Available in the docket: FMCSA-2004-19608-3961.

Cappuccio, F., Taggart, F., Ngianga-Bakwin, K., Currie, A., Peile, E., Stranges, S., and Miller, M., "Meta-Analysis of Short Sleep Duration and Obesity in Children and Adults," *Sleep*, Vol.31, No. 5, May 2008, pp. 619-626. Available in the docket: FMCSA-2004-19608-3962.

Centers for Disease Control and Prevention (CDC), "Perceived Insufficient Rest or Sleep – Four States, 2006," *Morbidity and Mortality Weekly Report*, Vol. 29, No. 57(08), February 2008, pp. 200-203. Available in the docket: FMCSA-2004-19608-3964.

Chami, H., Devereux, R., Gottdeiner, J., Mahra, R., Roman, M., Benjamin, E., and Gottleib, D., "Left Ventricular Morphology and Systolic Function in Sleep-Disordered Breathing," *Circulation*, Vol. 117, No. 20, May 2008, p. 2599. Available in the docket: FMCSA-2004-19608-3963.

Chen, J.C., Chen, Y.J., Chang, W.P., and Christiani, -D.C., "Long Driving Time Is Associated with Haematological Markers of Increased Cardiovascular Risk in Taxi Drivers," *Occupational and Environmental Medicine*, Vol. 62, No. 12, December 2005, pp. 890–894. Available in the docket: FMCSA-2004-19608-3965.

Czeisler, C., “Medical and Genetic Differences in the Adverse Impact of Sleep Loss on Performance: Ethical Considerations for the Medical Profession,” *Transactions of the American Clinical and Climatological Association*. Vol. 120, 2009, pp. 249-285. Available in the docket: FMCSA-2004-19608-3966.

Dahl, S., Kaerlev, L., Jensen, A., Tüchsen, F., Hannerz, H., Nielsen, P.S., and Olsen, J., “Hospitalization for Lifestyle Related Diseases in Long Haul Drivers Compared with Other Truck Drivers and the Working Population at Large,” *Work*, Vol. 33, 2009, pp. 345-353. Available in the docket: FMCSA-2004-19608-4000.

Di Milia, L. and Mummery, K., “The Association Between Job Related Factors, Short Sleep and Obesity,” *Industrial Health*, Vol. 47, 2009, pp. 363–368. Available in the docket: FMCSA-2004-19608-3967.

Dinges, D., Maislin, G., Krueger, G., Brewster, R., and Carroll, R., “Pilot Test of Fatigue Management Technologies,” 2005. Available in the docket: FMCSA-2004-19608-4025.

Ferrie, J., Shipley, M., Cappuccio, F., Brunner, E., Miller, M., Kumari, M., and 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.

Finkelstein, E.A., Brown, D.S., Wrage, L.A., Allaire, B. T., and Hoerger, T.J., “Individual and Aggregate Years-of-Life-Lost Associated with Overweight and Obesity,” *Obesity*, Vol. 18, No. 2, February 2010, pp. 333-339. Available in the docket: FMCSA-2004-19608-4006.

Flegal, K.M., Carroll, M.D., Ogden, C.L. and Johnson, C.L., “Prevalence and Trends in Obesity Among U.S. Adults, 1999-2008,” *Journal of the American Medical Association*, Vol. 303, No. 3, 2010, pp. 235-241. Available in the docket: FMCSA-2004-19608-3970.

Gangwisch, J., Heymsfield, S., Boden-Albala, B., Buijs, R., Kreier, F., Pickering, T., Rundle, A., Zammit, G., and Malaspina, D., “Short Sleep Duration as a Risk Factor for Hypertension: Analyses of the First National Health and Nutrition Examination Survey,” *Hypertension: Journal of the American Heart Association*, Vol. 47, April 2006, pp. 833-839. Available in the docket: FMCSA-2004-19608-3972.

Gottlieb, D., Punjabi, N., Newman, A., Resnick, H., Redline, S., Baldwin, C., and Nieto, J., “Association of Sleep Time with Diabetes Mellitus and Impaired Glucose Tolerance,” *Archives of Internal Medicine*, Vol. 165, April 2005, pp. 863-868. Available in the docket: FMCSA-2004-19608-3973.

Grandner, M. and Patel, N., “From Sleep Duration to Mortality: Implications of Meta-Analysis and Future Directions,“ *Journal of Sleep Research*, Vol. 18, 2009, pp. 145-147. Available in the docket: FMCSA-2004-19608-3974.

Grotle, M., Hagen, K., Natvig, B., Dahl, F., and Kvien, T., “Obesity and Osteoarthritis in Knee, Hip and/or Hand: An Epidemiological Study in the General Population with 10 years Follow-Up,” *Bio Med Central Musculoskeletal Disorders*, Vol. 9, No. 132, October 2008, n.p.. Available in the docket: FMCSA-2004-19608-3975.

Hamilton, M. T., Hamilton, D. G., and Zderic, T. W., “Role of Low Energy Expenditure and Sitting in Obesity, Metabolic Syndrome, Type 2 Diabetes, and Cardiovascular Disease,” *Diabetes*, Vol. 56, No. 11, November 1, 2007, pp. 2655 - 2667. Available in the docket: FMCSA-2004-19608-3976.

Hauner, H., “Overweight – Not Such a Big Problem,” *Deutsches Ärzteblatt International*, Vol. 106, No. 40, 2009, pp. 630-640. Available in the docket: FMCSA-2004-19608-3979.

Hayashino, Y., Fukuhara, S., Suzukamo, Y., Okamura, T., Tanaka, T., and Ueshima, H., “Relation Between Sleep Quality and Quantity, Quality of Life, and Risk of Developing Diabetes in Healthy Workers in Japan: the High-Risk and Population Strategy for Occupational Health Promotion (HIPOP-OHP) Study,” *Bio Med Central Public Health*, Vol. 7, No. 129, June 2007, n.p.. Available in the docket: FMCSA-2004-19608-3980.

Healy, G., Dunstan, D., Salmon, J., Cerin, E., Shaw, J., Zimmet, P., and Owen, N., “Breaks in Sedentary Time: Beneficial Associations with Metabolic Risk,” *Diabetes Care*, Vol. 31, No. 4, April 2008, pp. 661-666. Available in the docket: FMCSA-2004-19608-3981.

Katzmarzyk, P.T., Church, T.S., Craig ,C.L., and 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.

Knauth, P., “Extended Work Periods,” *Industrial Health*, Vol. 45, 2007, pp. 126-136. Available in the docket: FMCSA-2004-19608-4009.

Lenz, M., Richter, T., and Mühlhauser, I., “The Morbidity and Mortality Associated with Overweight and Obesity in Adulthood,” *Deutsches Ärzteblatt International*, Vol. 106, No.40, 2009, pp. 641-648. Available in the docket: FMCSA-2004-19608-4012.

Marshall, N., Wong, K., Liu, P., Cullen, S., Knuiman, M., and Grunstein, R., “Sleep Apnea as an Independent Risk Factor for All-Cause Mortality: the Busselton Health Study,” *Sleep*, Vol. 31, No. 8, 2008, pp. 1079-1085. Available in the docket: FMCSA-2004-19608-4013.

Marshall, N., Wong, K., Phillips, C., Liu, P., Knuiman, M., and Grunstein, R., “Is Sleep Apnea an Independent Risk Factor for Prevalent and Incident Diabetes in the Busselton Health Study?” *Journal of Clinical Sleep Medicine*, Vol. 5, No. 1, 2009, pp. 15-20. Available in the docket: FMCSA-2004-19608-4014.

Martin, B.C., Church, T.S., Bonnell, R., Ben-Joseph, R., and Borgstadt, T., “The Impact of Overweight and Obesity on the Direct Medical Costs of Truck Drivers,” *Journal of Occupational and Environmental Medicine*, Vol. 51, No. 2, February 2009, pp. 180 –184. Available in the docket: FMCSA-2004-19608-4004.

Mehra, R., Benjamin, E., Shahar, E., Gottlieb, D., Nawabit, R., Kirchner, H. Sahadevan, J., and Redline, S., “Association of Nocturnal Arrhythmias with Sleep-Disordered Breathing: The Sleep Heart Health Study,” *American Journal of Respiratory and Critical Care Medicine*, Vol. 173, 2006, pp. 910-916. Available in the docket: FMCSA-2004-19608-4015.

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

Mollicone, D. J., Van Dongen, H.P., Rogers, N.L., and Dinges, D.F., "Response Surface Mapping of Neurobehavioral Performance: Testing the Feasibility of Split Sleep Schedules for Space Operations," *Acta Astronaut*, Vol. 63, No. 7-10, 2008, pp. 833-840. Available in the docket: FMCSA-2004-19608-4017.

Mummery, W., Schofield, G., Steele, R., Eakin, E., and Brown, W., "Occupational Sitting Time and Overweight and Obesity in Australian Workers," *American Journal of Preventive Medicine*, Vol. 29, No., 2, August 2005, pp. 91-97. Available in the docket: FMCSA-2004-19608-4002.

National Institute of Diabetes and Digestive and Kidney Diseases, "Overweight and Obesity Statistics," February 2010. Available in the docket: FMCSA-2004-19608-3982.

Okada, M., Takamizawa, A., Tsushima, K., Urushihata, K., Fujimoto, K., and Kubo, K., "Relationship Between Sleep-Disordered Breathing and Lifestyle-Related Illnesses in Subjects Who Have Undergone Health-Screening," *Internal Medicine* (The Japanese Society of Internal Medicine), Vol. 45, No. 15, 2006, pp. 891-896. Available in the docket: FMCSA-2004-19608-3983.

Patel, S. and Hu, F., "Short Sleep Duration and Weight Gain: A Systematic Review," *Obesity*, Vol.16, No. 3, March 2008, pp. 643-653. Available in the docket: FMCSA-2004-19608-3984.

Punjabi, N., Caffo, B., Goodwin, J., Gottlieb, D., Newman, A., O'Connor, G., Rapoport, D., Redline, S., Resnick, H., Robbins, J., Shahar, E., Unruh, M., and Samet, J., "Sleep-Disordered Breathing and Mortality: A Prospective Cohort Study," *PLoS Medicine*, Vol. 6, No. 8, August 2009, n.p.. Available in the docket: FMCSA-2004-19608-3997.

Rosekind, M., Gregory, K., Mallis, M., Brandt, S., Seal, B., and Lerner, D., "The Cost of Poor Sleep: Workplace Productivity Loss and Associated Costs," *Journal of Occupational and Environmental Medicine*, Vol. 51, No. 1, January 2010, pp. 91-98. Available in the docket: FMCSA-2004-19608-4003.

Schoenborn, C. & Adams, P., "Sleep Duration as a Correlate of Smoking, Alcohol Use, Leisure-Time Physical Inactivity, and Obesity Among Adults: United States, 2004-2006," National Center for Health Statistics (CDC), NCHS Health E-Stats, May 2008. Available in the docket: FMCSA-2004-19608-3985.

Schulte, P., Wagner, G., Downes, A., and Miller, D., "A Framework for the Concurrent Consideration of Occupational Hazards and Obesity," *The Annals of Occupational Hygiene*, Vol. 52, No. 7, September 2008, pp. 555-566. Available in the docket: FMCSA-2004-19608-3988.

Seicean, S., Kirchner, H., Gottleib, D., Punjabi, N., Resnick, H., Sanders, M., Budhiraja, R., Singer, M. and Redline, S., "Sleep-Disordered Breathing and Impaired Glucose Metabolism in Normal-Weight and Overweight/Obese Individuals," *Diabetes Care*, Vol. 31, No. 5, May 2008, pp. 1001-1006. Available in the docket: FMCSA-2004-19608-3989.

Tamakoshi, A. and 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.

Van Cauter, E. and Knutson, K.L., "Sleep and the Epidemic of Obesity in Children and Adults," *European Journal of Endocrinology*, Vol. 159, 2008, pp. S59–S66. Available in the docket: FMCSA-2004-19608-3991.

Van Dongen, H. and Belenky, G., "Individual Differences in Vulnerability to Sleep Loss in the Work Environment," *Industrial Health*, Vol. 47, 2009, pp. 518-526. Available in the docket: FMCSA-2004-19608-3992.

Violanti, J., Burchfiel, C., Hartley, T., Mnatsakanova, A., Fekedulegn, D., Andrew, M., Charles, L., and Vila, B., "Atypical Work Hours and Metabolic Syndrome Among Police Officers," *Archives of Environmental and Occupational Health*, Vol. 64, No. 3, Fall 2009, pp. 194-201. Available in the docket: FMCSA-2004-19608-4005.

Appendix C – Costs, Benefits, and Net Benefits of HOS Rule Components and Sensitivity Analysis for Assumed Percentage of Fatigue Reduction

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Appendix C

Costs, Benefits, and Net Benefits of HOS Rule Components for Proposed Option and Sensitivity Analysis for Assumed Percentage of Fatigue Reduction

This Appendix first presents the results of the analysis broken down into the components of Options 2 through 4 under different assumption of baseline fatigue involvement. We present the costs, benefits, and net benefits of the following major components: 13 hours of work allowed per day, 10 hours of driving allowed per day, 9 hours of driving allowed per day, the 7-day restart restriction, the 2-night restart restriction, and the half-hour break requirement. These estimates are all for each component relative to the current rule. That is, we start with the current rule, add one component, and evaluate the costs and benefits relative to the current rule.

Because the provisions of the proposed rule overlap to some extent (e.g., reducing daily working hours is expected to reduce the use of the 11^{th} hour and also reduce weekly working hours), *the sum of the costs and benefits of the individual components does not equal the costs and benefits of the all of the components considered as a package*.

Cost of HOS Rule Components for 13 Percent Baseline Fatigue Level

We first present the cost of the HOS rule components assuming a baseline level of 13 percent fatigue involvement in crashes. Following OMB Circular A-4, we present all impacts discounted at both 7 percent and 3 percent. Exhibits C-1 through C-3 present the 10-year impacts discounted at 7 percent, and Exhibits C-4 through C-6 present the impacts discounted at 3 percent. Finally, Exhibits C-7 through C-9 show the annual impacts on which the discounted estimates were based. All dollar figures in the first six exhibits below are present values (2008$) over 10 years, rounded to the nearest $100 million; the dollar figures in Exhibits C-7, C-8, and C-9 are annual, and rounded to the nearest $10 million.

For this analysis we look at 6 separate components that encompass Option 2 through Option 4. Each of these options utilizes some portion of these components, making them unique. All the options incur costs due to the 7-day restart restriction, the 2-night restart restriction and ½ hour break requirement. Option 2 imposes a 13-hour limit on daily duty time and a 10-hour limit on driving time. Option 3 and 4 differ from Option 2 only in the amount of driving time allowed within a duty period. Option 3 allows for 11 hours of driving, or 1 hour more than Option 2. Option 4 allows for 9 hours of driving, or 1 hour less than Option 2.

Exhibit C-1 below shows the costs of the components discounted at 7 percent. The largest cost incurred is the 9-hour driving restriction, which is approximately $15.9 billion and only pertains to Option 4. The second largest discounted cost component, applying only to Option 2, is the 10-hour driving restriction, which equals $5.2 billion. The next largest cost component, which applies to Option 2 and Option 3 and equals $1.4 billion, is the 13-hour daily duty time restriction .

Exhibit C-1. Ten-Year Costs by Rule Component, Discounted at 7 Percent (Millions)
(excludes approximately $300 million for training and reprogramming)

13-Hour Working Restriction	10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Restriction	1/2 Hour Break Requirement
$1,400	$5,100	$15,900	$2,600	$500	$400

Exhibit C-2 presents the discounted benefits broken down into the various components. The 9-hour driving restriction is the largest benefit category when under all three baseline sleep assumptions.

Exhibit C-2. Ten-Year Benefits of by Rule Component, Discounted at 7 Percent (Millions)

Baseline Sleep Scenario	13-Hour Working Restriction	10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Restriction	1/2 Hour Break Requirement
Low Sleep	$5,600	$9,400	$21,400	$9,400	$1,800	$2,300
Medium Sleep	$4,000	$6,100	$12,600	$6,200	$1,200	$1,800
High Sleep	$2,300	$2,800	$3,700	$3,100	$600	$1,400

Exhibit C-3 displays the discounted net benefits broken down into the component restrictions. When we use the medium baseline sleep assumption, the 7-day restart restriction shows the largest net benefits at $3.7 billion. The second largest net benefits are those resulting from the 13-hour working restriction, which amounts to approximately $2.6 billion. Assuming low baseline sleep, the 7-day restart restriction is again the largest net benefit at approximately $6.8 billion. Under the low baseline sleep scenario, the net benefits for all of the components are positive. The net benefits become negative for the 9-hour driving restriction under the medium and high baseline sleep scenarios, amounting to negative $3.3 billion and negative $12.2 billion, respectively. In addition when we use the high baseline sleep assumption, the 10-hour driving restriction results in net benefits of negative $2.3 billion.

Exhibit C-3. Ten-Year Net Benefits by Rule Component, Discounted at 7 Percent (Millions)

Baseline Sleep Scenario	13-Hour Working Restriction	10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Restriction	1/2 Hour Break Requirement
Low Sleep	$4,300	$4,400	$5,600	$6,800	$1,300	$2,000
Medium Sleep	$2,600	$1,000	-$3,300	$3,700	$700	$1,400
High Sleep	$900	-$2,300	-$12,200	$500	$100	$1,000

Exhibit C-4 shows the costs of the components discounted at 3 percent. The largest discounted cost is incurred due to the 9-hour driving restriction, which is approximately $18.6 billion. The second largest discounted cost component is the 10-hour driving restriction, which amounts to $6.0 billion.

Exhibit C-4. Ten-Year Costs by Rule Component, Discounted at 3 Percent (Millions)
(excludes approximately $300 million for training and reprogramming)

13-Hour Working Restriction	10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Restriction	1/2 Hour Break Requirement
$1,700	$6,000	$18,600	$3,000	$600	$400

Exhibit C-5 presents the discounted benefits of the proposed option broken down into the six components. Using a discount rate of 3 percent, the 9-hour driving restriction results in the largest benefits ($25.0 billion) when we use the low baseline sleep assumption. Under the medium and high baseline sleep assumptions, the 9-hour restriction is still the largest component at approximately $14.7 and $4.3 billion, respectively.

Exhibit C-5. Ten-Year Benefits by Rule Component, Discounted at 3 Percent (Millions)

Baseline Sleep Scenario	13-Hour Working Restriction	10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Restriction	1/2 Hour Break Requirement
Low Sleep	$6,600	$11,100	$25,000	$11,000	$2,100	$2,700
Medium Sleep	$4,700	$7,100	$14,700	$7,300	$1,400	$2,100
High Sleep	$2,700	$3,300	$4,300	$3,600	$700	$1,600

Exhibit C-6 displays the discounted net benefits broken down into the six components. When we use the medium baseline sleep assumption, the 7-day restart restriction results the largest net benefits - approximately $4.3 billion. When we use the low baseline sleep assumption, the 7-day restart restriction again shows the largest net benefits at approximately $7.9 billion. Using low baseline sleep, the net benefits for all of the proposed option's components are positive. When we use the high baseline sleep assumption, the 10-hour driving restriction and the 9-hour driving restriction result in net benefits equal to negative $2.7 billion and negative $14.4 billion, respectively. We obtained a similar result for the 9-hour driving restriction using the medium baseline sleep scenario, with net benefits amounting to negative $3.9 billion.

Exhibit C-6. Ten-Year Net Benefits by Rule Component, Discounted at 3 Percent (Millions)

Baseline Sleep Scenario	13-Hour Working Restriction	10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Restriction	1/2 Hour Break Requirement
Low Sleep	$5,000	$5,100	$6,500	$7,900	$1,500	$2,300
Medium Sleep	$3,000	$1,100	-$3,900	$4,300	$800	$1,700
High Sleep	$1,100	-$2,700	-$14,200	$600	$100	$1,100

To compare these component net benefits across the options, we can sum the individual components of Options 2 through 4. Since all the options assume the 7-day restart, the 2-night restart restriction, and the ½ hour break requirement, we can compare the differences for these options by only considering the driving time and working time restrictions. Option 2 restricts driving time to 10 hours working time to 13 hours, resulting in net benefits of $10.1 billion for the low sleep scenario, $4.1 billion for the medium sleep scenario, and -$1.1 billion for the high sleep scenario. For Option 3, we only need to consider the 13 hour working restriction, thus the comparable benefits for the low, medium and high baseline sleep scenarios are $5.0 billion, $3.0 billion and $1.1 billion, respectively. Finally, for Option 4, we only need to consider the 9-hour driving restriction, thus the incremental net benefits for low, medium and high sleep scenarios are $6.5 billion, negative $3.9 billion and negative $14.2 billion, respectively.

Exhibits C-7, C-8, and C-9 show the annual costs, benefits, and net benefits of the components. These tables were the basis for the present value estimates presented in the first six exhibits.

Exhibit C-7. Annual Costs by Rule Component (Millions)
(excludes approximately $40 million for training and reprogramming)

13-Hour Working Restriction	10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Restriction	1/2 Hour Break Requirement
$190	$680	$2,120	$340	$70	$50

Exhibit C-8. Annual Benefits by Rule Component (Millions)

Baseline Sleep Scenario	13-Hour Working Restriction	10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Restriction	1/2 Hour Break Requirement
Low Sleep	$750	$1,260	$2,850	$1,250	$240	$310
Medium Sleep	$530	$810	$1,670	$830	$160	$240
High Sleep	$310	$370	$490	$410	$80	$180

Exhibit C-9. Annual Net Benefits by Rule Component (Millions)

Baseline Sleep Scenario	13-Hour Working Restriction	10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Restriction	1/2 Hour Break Requirement
Low Sleep	$570	$580	$740	$900	$170	$260
Medium Sleep	$340	$130	-$440	$490	$90	$190
High Sleep	$120	-$310	-$1,620	$70	$10	$130

Next, we present the results of the analysis broken down into the components of and estimated using alternative assumptions for the baseline percentage of crashes due to fatigue (7 and 18 percent baseline fatigue levels). We present the costs, benefits, and net benefits of the proposed option for the same major components as shown above. We again present these estimates for each component relative to the current rule.

Exhibits C-10 through C-18 present the impacts estimated using the 7 percent fatigue-related crashes assumptions. Exhibits C-10 through C-12 present the impacts discounted at 7 percent, Exhibits C-13 through C-15 present the impacts discounted at 3 percent, and Exhibits C-16 through C-18 show the annual impacts on which the discounted estimates were based.

Exhibits C-19 through C-24 present the impacts estimated using the 18 percent fatigue-related crashes assumption. Exhibits C-19 and C-20 present the impacts discounted at 7 percent, Exhibits C-21 and C-22 present the impacts discounted at 3 percent, and Exhibits C-23 and C-24 show the annual impacts on which the discounted estimates were based.

All dollar figures in Exhibits C-10 through C-15 and Exhibits C-19 through C-22 are present values (2008$) over 10 years, rounded to the nearest $100 million; the dollar figures in Exhibits C-16 through C-18 and C-23 and C-24 are annual and rounded to the nearest $10 million.

The cost of each component is not a function of the percent of fatigue-related crashes so we repeat our presentation of the cost estimates only once for brevity. Exhibit C-10 presents the costs discounted at 7 percent, Exhibit C-13 presents the costs discounted at 3 percent, and Exhibit C-16 presents the annual costs on which the discounted estimates were based.

Cost of HOS Rule Components for 7 Percent Baseline Fatigue Level

Exhibit C-10. Costs by Rule Component, Discounted at 7 Percent (Millions)
(excludes approximately $300 million for training and reprogramming)

13-Hour Working Restriction	10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Restriction	1/2 Hour Break Requirement
$1,400	$5,100	$2,120	$2,600	$500	$400

Exhibit C-11. Benefits of Rule Component – Using 7 Percent Fatigue, Discounted at 7 Percent (Millions)

Baseline Sleep Scenario	13-Hour Working Restriction	10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Restriction	1/2 Hour Break Requirement
Low Sleep	$4,900	$7,800	$17,600	$8,400	$1,600	$1,800
Medium Sleep	$3,200	$4,500	$8,600	$5,300	$1,000	$1,400
High Sleep	$1,500	$1,100	-$200	$2,200	$400	$800

Exhibit C-12. Net Benefits by Rule Component – Using 7 Percent Fatigue, Discounted at 7 Percent (Millions)

Baseline Sleep Scenario	13-Hour Working Restriction	10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Restriction	1/2 Hour Break Requirement
Low Sleep	$3,500	$2,700	$1,700	$5,900	$1,100	$1,400
Medium Sleep	$1,800	-$600	-$7,200	$2,700	$500	$1,000
High Sleep	$200	-$4,000	-$16,100	-$400	-$200	$500

Exhibit C-13. Costs by Rule Component, Discounted at 3 Percent (Millions)
(excludes approximately $300 million for training and reprogramming)

13-Hour Working Restriction	10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Restriction	1/2 Hour Break Requirement
$1,700	$6,000	$18,600	$3,000	$600	$400

Exhibit C-14. Benefits by Rule Component – Using 7 Percent Fatigue, Discounted at 3 Percent (Millions)

Baseline Sleep Scenario	13-Hour Working Restriction	10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Restriction	1/2 Hour Break Requirement
Low Sleep	$5,700	$9,100	$20,600	$9,800	$1,800	$2,100
Medium Sleep	$3,800	$5,300	$10,100	$6,200	$1,100	$1,600
High Sleep	$1,800	$1,300	-$300	$2,500	$400	$1,000

Exhibit C-15. Net Benefits by Rule Component – Using 7 Percent Fatigue, Discounted at 3 Percent (Millions)

Baseline Sleep Scenario	13-Hour Working Restriction	10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Restriction	1/2 Hour Break Requirement
Low Sleep	$4,000	$3,200	$1,900	$6,900	$1,200	$1,700
Medium Sleep	$2,100	-$700	-$8,400	$3,200	$500	$1,100
High Sleep	$200	-$4,700	-$18,800	-$400	-$200	$500

Exhibit C-16. Annual Costs by Rule Component (Millions)
(excludes approximately $40 million for training and reprogramming)

13-Hour Working Restriction	10-Hour Driving Restriction	10-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Restriction	1/2 Hour Break Requirement
$190	$680	$2,120	$340	$70	$50

Exhibit C-17. Annual Benefits of by Rule Component – Using 7 Percent Fatigue (Millions)

Baseline Sleep Scenario	13-Hour Working Restriction	10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Restriction	1/2 Hour Break Requirement
Low Sleep	$650	$1,040	$2,340	$1,120	$210	$240
Medium Sleep	$430	$600	$1,150	$710	$130	$180
High Sleep	$200	$150	-$30	$290	$50	$110

Exhibit C-18. Annual Net Benefits of by Rule Component – Using 7 Percent Fatigue (Millions)

Baseline Sleep Scenario	13-Hour Working Restriction	10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Restriction	1/2 Hour Break Requirement
Low Sleep	$460	$360	$220	$780	$140	$190
Medium Sleep	$240	-$80	-$960	$360	$60	$130
High Sleep	$20	-$530	-$2,140	-$50	-$20	$60

Cost of HOS Rule Components for 18 Percent Baseline Fatigue Level

Exhibit C-19. Benefits by Rule Component – Using 18 Percent Fatigue, Discounted at 7 Percent (Millions)

Baseline Sleep Scenario	13-Hour Working Restriction	10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Restriction	1/2 Hour Break Requirement
Low Sleep	$6,300	$10,700	$24,700	$10,100	$2,000	$2,700
Medium Sleep	$4,600	$7,400	$15,900	$7,000	$1,400	$2,300
High Sleep	$2,900	$4,100	$6,900	$3,800	$800	$1,700

Exhibit C-20. Net Benefits by Rule Component – Using 18 Percent Fatigue, Discounted at 7 Percent (Millions)

Baseline Sleep Scenario	13-Hour Working Restriction	10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Restriction	1/2 Hour Break Requirement
Low Sleep	$4,600	$5,300	$8,800	$7,500	$1,500	$2,300
Medium Sleep	$2,900	$2,000	-$100	$4,400	$900	$1,900
High Sleep	$1,200	-$1,400	-$8,900	$1,300	$300	$1,400

Exhibit C-21. Benefits by Rule Component – Using 18 Percent Fatigue, Discounted at 3 Percent (Millions)

Baseline Sleep Scenario	13-Hour Working Restriction	10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Restriction	1/2 Hour Break Requirement
Low Sleep	$7,400	$12,700	$28,900	$11,900	$2,400	$3,200
Medium Sleep	$5,400	$8,800	$18,500	$8,200	$1,700	$2,600
High Sleep	$3,400	$4,800	$8,100	$4,500	$1,000	$2,000

Exhibit C-22. Net Benefits by Rule Component – Using 18 Percent Fatigue, Discounted at 3 Percent (Millions)

Baseline Sleep Scenario	13-Hour Working Restriction	10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Restriction	1/2 Hour Break Requirement
Low Sleep	$5,400	$6,200	$10,300	$8,800	$1,800	$2,700
Medium Sleep	$3,300	$2,400	-$100	$5,200	$1,100	$2,200
High Sleep	$1,400	-$1,600	-$10,500	$1,500	$400	$1,600

Exhibit C-23. Annual Benefits by Rule Component – Using 18 Percent Fatigue (Millions)

Baseline Sleep Scenario	13-Hour Working Restriction	10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Restriction	1/2 Hour Break Requirement
Low Sleep	$840	$1,440	$3,290	$1,350	$270	$360
Medium Sleep	$610	$1,000	$2,110	$930	$190	$300
High Sleep	$390	$550	$920	$510	$110	$230

Exhibit C-24. Net Benefits by Rule Component – Using 18 Percent Fatigue (Millions)

Baseline Sleep Scenario	13-Hour Working Restriction	10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Restriction	1/2 Hour Break Requirement
Low Sleep	$610	$710	$1,170	$1,000	$200	$310
Medium Sleep	$380	$270	-$10	$590	$120	$250
High Sleep	$160	-$180	-$1,190	$170	$40	$180

Net Benefit Assumptions for Elimination of Fatigue

The net benefit estimates shown above and in the RIA 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 C-25 through C-27 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 C-25. Safety Benefits for **Option 2** (Millions)
(Assumes 13 Percent Baseline Fatigue Involvement)

Assumed Percent of Fatigue-involved Crashes Prevented if Fatigue is Eliminated	Benefits due to Reduced Acute Time on Task Effect	Benefits due to Reduced Cumulative Time on Task Effect	Total Benefits due to Reduced Crashes
100%	$190	$540	$730
50%	$90	$270	$360

Exhibit C-26. Annual Benefits for **Option 2** (Millions)
(Assumes 13 Percent Baseline Fatigue Involvement)

Assumed Percent of Fatigue-involved Crashes Prevented if Fatigue is Eliminated	Assumed Baseline Amount of Nightly Sleep		
	Low Sleep	Medium Sleep	High Sleep
100%	$2,210	$1,420	$620
50%	$1,850	$1,050	$260

Exhibit C-27. Annual Net Benefits for **Option 2** (Millions)
(Assumes 13 Percent Baseline Fatigue Involvement)

Assumed Percent of Fatigue-involved Crashes Prevented if Fatigue is Eliminated	Assumed Baseline Amount of Nightly Sleep		
	Low Sleep	Medium Sleep	High Sleep
100%	$1,180	$380	-$410
50%	$820	$20	-$770

Appendix D – Detailed Calculations of Costs and Benefits of HOS Rule

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Appendix D –
Detailed Calculations of Costs and Benefits of HOS Rule

Costs of Operational Changes

This section presents the details of the calculation of the operational costs of the HOS rule for Option 2. The methodology is described in detail in Chapter 3. In the chapter, the calculations for the operational costs for one driver group are shown in full. This appendix provides the details for the calculations for the other driver groups.

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 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.

To estimate the impacts on the existing patterns of work, we divided the provisions into three distinct effects: the effect of cutting the working hours from 14 to 13 hours per day, the effect of cutting back the maximum driving hours from 11 to 10 hours per day and the effect of the new restart provisions.

To estimate the productivity effects on the shift from a 14 to a 13 hour day, we used industry data to allocate the use of this last hour of the work day. It is estimated that 9 percent of drivers use this 14th hour of work and of the 9 percent, 60 percent of extreme intensity drivers, 25 percent of very high intensity drivers, 7 percent of high intensity drivers and 2 percent of moderate intensity drivers use this 14th hour. Similarly, we estimate the use of the 11th hour of driving. Industry data indicates that 21 percent of daily tours use this 11th hour. We assume that 70 percent of extreme intensity drivers, 50 percent of very high intensity drivers, 25 percent of high intensity drivers and 10 percent of moderate intensity drivers use this 11th hour.

To estimate the 14th hour reduction in the working day in terms of productivity impacts, we assume that a portion of this lost hour is redistributed to other days of less driving intensity. Most drivers do not operate at the limits of the current rule and thus would likely transfer some of this time to other less intense work days. In addition, this extra hour in many cases would have been used for an off-duty break and thus would not affect productivity. We assume that the moderate intensity driver is unaffected by this change because they are not typically driving in this 14th hour, and if they were they would have the flexibility in their schedule to shift the hour to another day. We assume the high intensity driver uses 1/2 of that 14th hour as a break and would shift 1/2 of the remaining 30 minutes to another day. The very high intensity driver uses 3/4 of an hour as break and shifts 1/3 of the remaining time to another day (1/3 of 1/4 of an hour). Finally for the extreme intensity driver, we assume that 1 hour was dedicated to a break and that no time is shifted to another day.

To calculate the productivity impact, we multiplied the percent of trips that use the 14th hour by the non-use factor and by the portion of remaining time not able to be shifted. We then divide this total by the average number of hours worked per day to estimate the productivity impact. For the very high intensity driver, this calculation results in a 1.07 percent loss in productivity per day ([25% x 3/4 hours x 2/3] / 11.7 hours). We also calculate the hours lost per week per driver group. This is estimated by multiplying the percent of trips by the non-use factor and by the fraction of time that cannot be shifted. Finally, we multiply this total by the days expected to work in a week. As shown in column G of Exhibit D-1 for a very high intensity driver this resulted in 0.75 hours lost a week (25% x 3/4 hours x 2/3 x 6 days). Exhibit D-1 summarizes these assumptions and calculations for all driver groups.

Exhibit D-1. Calculation of Productivity Impacts of Reducing Daily Work Time

Driver Group	Percent of Trips that Use the 14th Hour of Work	Non Use Factor	Portion of Time Lost	Average Number of Hours Worked Per Day	Days Expected to Work in a Week	Unweighted Productivity Impact	Hours Lost Per Week - 14 Hour
	A	B	C	D	E	F = (A x B x C) / D	G = A x B x C x E
Moderate	2%	0	0	9.0	5	0.00%	0.00
High	7%	1/2	1/2	10.0	6	0.18%	0.11
Very High	25%	3/4	2/3	11.7	6	1.07%	0.75
Extreme	60%	1	1	13.3	6	4.50%	3.60

We next calculate the productivity lost due to a shift from an 11 to a 10 hour driving day. These calculations parallel the 14th hour calculations with assumptions on the amount of lost time that can be shifted to another day. Because these are direct driving hours, no time is considered an off-duty break. To estimate the impact on productivity for the reduced driving time we multiply the percent of trips that use the 11th hour by the time that is not able to be shifted to another day and divide that total by the average number of driving hours per day. As shown in column E of Exhibit D-2 for the very high intensity driver group, this resulted in a 4.17 percent productivity drop (50% x 0.75 hours / 9 hours). Next, we calculate the hours lost by multiplying the percent of trips using the 11th hour by the potion of hours lost and finally by the days expected to work in a week. As shown in column F in Exhibit D-2 for the very high intensity driver, this resulted in 2.25 hours lost a week due to the reduction in total driving time (50% x 0.75 hours x 6 days). Exhibit D-2 summarizes these assumptions and calculations for each of the driver groups.

Exhibit D-2. Calculation of Productivity Impacts of Reducing Daily Driving Time

Driver Group	Percent of Trips that Use the 11th Driving Hour	Portion of Time Lost	Average Number of Hours Driving Per Day	Days Expected to Work in a Week	Unweighted Productivity Impact	Hours Lost Per Week – 11th Hour (Unadjusted)
	A	B	C	D	E = (A x B)/C	F = A x B x D
Moderate	10%	0.55	7.0	5	0.79%	0.28
High	25%	0.65	8.0	6	2.03%	0.98
Very High	50%	0.75	9.0	6	4.17%	2.25
Extreme	70%	0.85	10.0	6	5.95%	3.57

Next, as discussed in Chapter 3 of the RIA, we weight these productivity totals and adjust for double counting, because hours lost due to a shortened work day and from shortened driving time are likely to overlap. To weight the productivity losses, we multiply the productivity impact by the percent of work effort for each category. As shown in columns C and E of Exhibit D-3 for the very high intensity driver group, this resulted in a productivity loss of 0.144 percent for reduction in daily work time (13.4% x 10.7%) and 0.56 percent for the reduction in daily driving time (13.4% x 4.17%). Lastly to avoid double counting, we subtract a portion of the weighted productivity loss due to the reduction in working hours from the weighted productivity loss due to the reduction in driving hours. We assume that 50 percent of the productivity loss from the daily working time was due to the reduction in daily driving time. As shown in column F of Exhibit D-3 for the very high intensity driver group, this calculation resulted in an adjusted weighted productivity loss of 0.49 percent (0.56% - [50% x 0.144%]). Exhibit D-3 below shows the calculations of the four driver groups for both their weighted productivity losses and for the adjusted productivity loss for daily driving hours.

Exhibit D-3. Calculation of Weighted Productivity Impacts and Adjustments for Double Counting

Driver Group	Percent of Work Effort	Unweighted Productivity Impact – 14th Hour of Work	Weighted Productivity Impact – 14th hour	Unweighted Productivity Impact – 11th Hour Driving	Weighted Productivity Impact – 11th Hour Driving (Without Double Counting Adjustment)	Weighted Productivity Impact – 11th Hour Driving (With Double Counting Adjustment)
	A	**B**	**C = A x B**	**D**	**E = A x D**	**F = E - (C x 50%)**
Moderate	57.00%	0.00%	0.000%	0.79%	0.45%	0.45%
High	21.90%	0.18%	0.038%	2.03%	0.44%	0.43%
Very High	13.40%	1.07%	0.144%	4.17%	0.56%	0.49%
Extreme	7.70%	4.50%	0.347%	5.95%	0.46%	0.28%

The last piece of determining the operation costs was to calculate the cost of the new restart provision. This provision allows drivers to restart their work week if they take a break up to 34 hours and includes two periods from 11:00 PM to 7:00 AM. The provision only affects drivers who work 60 hours or more, and thus only affects the very high and extreme intensity driver groups.

In order to estimate the restart provision, we first estimate the total lost hours of both the daily work restriction and the daily driving restriction. We already calculated the lost hours above for each of the two provisions, but to accurately account for the total lost hours, we need to adjust for double counting as we did before. To adjust the hours lost per week due to the reduction in daily driving hours we subtract 50 percent of the hours lost due to the shortened work day, calculated by multiplying the hours lost per week from the reduction in working hours by the average number of hours per driving day divided by the average number of hours worked per driving day. As shown in column E of Exhibit D-4 for the very high intensity driver group, this calculation resulted in 1.96 hours lost per week (2.25 hours – 50% x [0.75 hours x 9 hours] / 11.67 hours). The calculations for each driver group are displayed below in Exhibit D-4.

Exhibit D-4. Weighted Hours Lost with Double Counting Adjustments

Driver Group	Hours Lost Per Week - 14 Hour	Hours Lost Per Week – 11th Hour (Without Double Counting Adjustment)	Average Number of Hours Driving per Day	Average Number of Hours Worked per Day	Hours Lost Per Week – 11th Hour (With Double Counting Adjustment)
	A	B	C	D	E = B - 50% x (A x C) / D
Moderate	0	0.275	7.0	9.00	0.28
High	0.105	0.975	8.0	10.00	0.93
Very High	0.75	2.25	9.0	11.67	1.96
Extreme	3.6	3.57	10.0	13.33	2.22

With the calculation of the adjusted hours lost, we can now calculate the productivity loss due to the restart provision. Since the restart provision only affects those driving over 60 hours a week, there is no impact on the moderate and high intensity driver groups. For the very high intensity drivers, the hours lost per week was assumed to be 0.7 hours. 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 hours) and subtracting the hours lost due to the restrictions in daily work time (3.60 hours) and the hours lost due to the restriction in daily driving time (2.22 hours) minus 70 hours, which is allowed under the new restart provisions. As shown in column A of Exhibit D-5, the loss of 0.7 hours per week due to the 2-night restriction in the restart provision was added to this number, to arrive at a total of 4.88 hours ([80 hours – 3.60 hours – 2.22 hours – 70 hours] + 0.70 hours) 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 extreme intensity drivers, the loss of 4.88 hours 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 (to weight the productivity). As shown in column D of Exhibit D-5 for the extreme intensity drivers, this calculation resulted in a total of 0.470 percent (4.88 hours / 80 hours x 7.7%) of lost productivity for this group of drivers due to the restart provision. We performed a similar calculation for the drivers with very high intensity schedules. Exhibit D-5 below shows these calculations.

Exhibit D-5. Calculation of Productivity Impacts of the Restart Provision

Driver Group	Hours Lost Per Week	Average Hours Worked Per Week	Percent of Work Effort	Lost Productivity
	A	B	C	D = A / (B x C)
Moderate	0	45	57.00%	0.000%
High	0	60	21.90%	0.000%
Very High	0.7	70	13.40%	0.134%
Extreme	4.88	80	7.70%	0.470%

The next step was to monetize these changes in productivity due to the three major changes resulting from the HOS rule provisions. As calculated in chapter 3 of the RIA, we estimate the cost of a one percent loss in productivity to be $356 million. In Exhibit D-6 below, we calculate the total productivity loss for each provision by summing across the driver groups. For instance, the total productivity loss for the reduction in daily driving hours was 1.624% (0.448% for moderate intensity drivers + 0.426% for high intensity drivers + 0.487% for very high intensity drivers + 0.285% for extreme intensity drivers). We then multiplied this total percent by the cost of a 1 percent loss in productivity to estimate the total cost of reducing the driving hours at $585.62 million (1.645% x $356 million). The calculations for each HOS provision are displayed in Exhibit D-6.

Exhibit D-6. Monetized Changes in Productivity

Driver Group	Weighted Productivity Impact – 14th Hour	Weighted Productivity Impact – 11th Hour Driving (With Double Counting Adjustment)	Weighted Productivity Impact - Restart Provision
Moderate	0.000%	0.448%	0.000%
High	0.038%	0.426%	0.000%
Very High	0.144%	0.487%	0.134%
Extreme	0.347%	0.285%	0.470%
Total Productivity Loss	**0.528%**	**1.645%**	**0.604%**
Total Cost - $356 Million Per 1% (Millions)	**$188.11**	**$585.62**	**$214.92**

Lastly, we estimated the total productivity lost in terms of hours per week. As shown in column D of Exhibit D-7, the total productivity lost for the very high intensity driver group was 3.41 hours. This is calculated by summing across the 3 types of rule provision discussed above, including 0.75 hours lost from a reduction in the daily work time, 1.96 hours lost due to the reduction in the daily driving time and 0.7 hours lost due to the restart provisions. The calculations for each driver group are summarized in Exhibit D-7.

Exhibit D-7. Total Impact Due to Changes in Productivity

Driver Group	Hours Lost Per Week - daily work	Hours Lost Per Week – Driving	Restart Hour Lost Per Week	Total Hours Lost
	A	**B**	**C**	**D = A + B + C**
Moderate	0	0.28	0	0.28
High	0.105	0.93	0	1.04
Very High	0.75	1.96	0.7	3.41
Extreme	3.6	2.22	4.88	10.70

Safety Benefits

This section presents the details of the calculation of the safety benefits of the HOS rule for Option 2. The methodology is described in detail in Chapter 4. In the chapter, the calculations for the safety benefits for one driver group are shown in full. This appendix provides the details for the calculations for the other driver groups.

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.

As discussed in Chapter 4, 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, as shown in column D of Exhibit D-8, this calculation results in a total of 1.5 hours affected (25% x 1 hour x 6 tours/week) for the high intensity driver group. As shown in Exhibit D-8, this calculation was 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.

Next, the total lost hours due to the 11th hour restriction was 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 work day) for each driver category. As shown in column G of Exhibit D-8, this resulted in a total of 14.25 hours (1.5 hours x 19% x 50 weeks) affected per year per driver for the high intensity driver group. As shown in Exhibit D-8, we repeated this calculation for each category of drivers and summed them to obtain a total of 56.25 hours affected per year per driver due to the 11th hour restriction. We then multiplied this total by the total number of drivers to obtain a total of 90 million (56.25 hours x 1,600,000 drivers) hours lost per year due to the 11th hour restriction.

Exhibit D-8. Driving Time Lost Due to 11th Hour Restriction

Driver Group	**Percent of Trips that Use the 11th Driving Hour**	**Loss of Hours**	**Days Expected to Work in a Week**	**Hours Affected by 11th Hour Reduction**	**Percentage of Workforce**	**Weeks per Year**	**Hours Affected per Year Per Driver, Weighted**
	A	**B**	**C**	**D = A x B x C**	**E**	**F**	**G = D x E x F**
Moderate	10%	1	5	0.5	66%	50	16.5
High	25%	1	6	1.5	19%	50	14.25
Very High	50%	1	6	3	10%	50	15
Extreme	70%	1	6	4.2	5%	50	10.5
Hours per Driver							**56.25**
Total Hours Lost							**90,000,000**

In calculating the hours affected due to the 11th hour restriction, we also accounted 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 were multiplied by the percent of an hour which that group of drivers would be able to shift to another day. As shown in Exhibit D-9, the total hours lost for the moderate, high, very high, and extreme intensity groups were 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 were summed to obtain the total number of hours shifted to another day. We then divided 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 resulted 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, and conversely 32 percent of the lost 11th hours that would be shifted to another day.

Exhibit D-9. Percentage of Driving Time Lost and Shifted to Another Day Due to 11th Hour Restriction

Driver Group	Percent of Trips that Use the 11th Driving Hour	Loss of Hours	Days Expected to Work in a Week
	A	**B**	**C = A x B**
Moderate	16.5	0.45	7.425
High	14.25	0.35	4.9875
Very High	15	0.25	3.75
Extreme	10.5	0.15	1.575
Hours per Driver			**17.7375**
Percent of Hours Shifted to Another Day (D = 17.7375 / 56.25)			**32%**
Percent of Hours Lost Due to 11th Hour (E = 1 – D)			**68%**

As discussed in Chapter 4, we next calculated the value per hour of the change in risk from removing the 11th hour. This value per hour was 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 driving is reallocated to a new driver, we first determined the change in the percentage of fatigue involvement when the restricted 11th hour driving is reallocated to a new driver. The change in the fatigue level was thus the scaled percent of fatigue involvement in the 11th hour (35.7 percent) minus the average percent fatigue involvement for all other hours (13 percent), or 22.7 percent (35.7% - 13%). We next multiplied this change in the percent fatigue involvement by the average crash cost per hour of driving. As shown in column D of Exhibit D-10, this resulted in a value of $2.35 (22.7% x $10.33) per hour of the change in fatigue risk from removing the 11th hour when the restricted driving is reallocated to another driver. We also calculated this value for the upper- and lower-bound fatigue levels.

Next, we repeated this calculation for the second scenario where the restricted 11th hour driving is shifted to other days by the same driver. We made a similar calculation for the change in fatigue level, except for this calculation we used 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 their other driving days. For this scenario, the change in fatigue level was thus the scaled percent fatigue involvement in the 11th hour (35.7 percent) minus the average percent fatigue involvement for hours 6 through 10 (22.3 percent), or 13.4 percent (35.7% - 22.3%). We next multiplied this change in the percent fatigue involvement by the average crash cost per hour of driving. As shown column E of Exhibit D-10, this resulted in a value of $1.38 (13.4 % x $10.33) 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. Similar calculations were made using the upper- and lower-bound fatigue levels.

Exhibit D-10. Value per Hour of Change in Risk from Removing 11th Hour

Fatigue Level	Reduction in Likelihood by Eliminating the 11th Hour - Shift to a Typical Driver	Reduction in Likelihood by Eliminating the 11th hour - Shift Same Driver	Average Cost Crash per Hour of Driving	Value of the Change in Risk Fatigue - Shift to a Typical Driver	Value of the Change in Risk Fatigue - Shift to Same Driver
	A	B	C	D = A x C	E = B x C
Lower-bound	29.1%	14%	$10.33	$3.01	$1.47
Median	23.1%	14%	$10.33	$2.39	$1.47
Upper-bound	18.1%	14%	$10.33	$1.87	$1.47

Now that we had an estimated value per hour of the change in risk from removing the 11th hour for both of the possible scenarios discussed above, we calculated the weighted value per hour of the change in risk. For this calculation, we used the percentage of the restricted 11th hour driving that was lost and redistributed to another driver rather than shifted to another day by the same driver, which was calculated above (68%). We obtained 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 ($2.35) by the assumed percent of hours for this scenario (68%) and the value per hour for hours that are shifted to another driver ($1.38) by the assumed percent of hours for this scenario (100% - 68% = 32%). As shown in column E of Exhibit D-11, this calculation resulted in a weighted value per hour of the change in fatigue risk of $2.04 ([$2.35 x 68%] + [$1.38 x 32%]). This weighted value per hour of the change in fatigue risk was then multiplied by the hours per year lost due to the 11th hour restriction calculated above (90 million) to obtain a total of $184 million for the safety benefit due to the change in daily driving time. Similar calculations were 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.

Exhibit D-11. Total Safety Benefit for Reduction in Driving Due to 11th Hour Restriction

Fatigue Level	Value of the Change in Risk Fatigue - Shift to a Typical Driver	Value of the Change in Risk Fatigue - Shift to Same Driver	Percent of Hours Lost Due to 11th Hour	Percent of Hours Shifted to Another Day	Weighted Value Per Hour	Hours Per Year Lost Due to the 11th hour Reduction (Millions)	Total Safety Benefit for the Reduction in the 11th Hour (Millions)
	A	B	C	D	E = (A x C) + (B x D)	F	G = E x F
Lower-bound	$3.01	$1.47	68%	32%	$2.52	90	$226.61
Median	$2.39	$1.47	68%	32%	$2.10	90	$188.67
Upper-bound	$1.87	$1.47	68%	32%	$1.75	90	$157.06

Next, we estimated the safety benefits due to the change in weekly work time. The first step of estimating safety benefits of reducing weekly work time was to determine the weekly work time for each category of drivers after the new HOS rule would go into effect. For each category of drivers, we started with the assumed average work time as shown in Exhibit 2-6 of the RIA and subtracted from it the change in weekly work time as calculated in the operational changes chapter. For example, as shown in Exhibit D-12 for the very high intensity driver group, the estimated change in their weekly work time (3.41 hours) was subtracted from their average weekly work time (70 hours) to obtain a new average weekly work time of just under 67 hours. As shown in Exhibit D-12, this calculation was repeated for the other driver groups.

Exhibit D-12. Change in Weekly Work Time Due to the HOS Rule

Driver Group	Average Hours Worked Per Week	Total Change in Weekly Work Time	New Average Weekly Work Time
	A	**B**	**C = A - B**
Moderate	45	0.28	44.73
High	60	1.04	58.96
Very High	70	3.41	66.59
Extreme	80	10.70	69.30

Next, for each total weekly work time, the number of average hours worked was converted to a fatigue percentage using a cumulative fatigue function estimated using data from the LTCCS. This function was based on the dashed curve in Exhibit 4-13 of the RIA. For example, as shown in column B of Exhibit D-13 for the very high intensity driver group, a weekly work schedule of 70 hours per week is associated with a 22.3 percent fatigue level. This is compared to the fatigue level of 13 percent for a driver with an average schedule of 52 hours per week (as described in the industry profile section). For the very high intensity driver group, 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 9.3 percent (22.3% - 13%).

We next used the average crash cost per hour of driving 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. For example, for the very high intensity drivers, the $10.33 average crash cost per hour of driving is multiplied by the reduction in weekly work time for this group (3.41 hours) and by the percent reduction in fatigue that results from a driver working an intense schedule versus a driver working an average schedule (9.7 percent). As shown in column E of Exhibit D-13 for the very high intensity drivers, this calculation resulted in a value of $3.28 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 was then repeated for each category of drivers and for each baseline fatigue level, as shown in Exhibit D-13.

Exhibit D-13. Value of Redistributed Driving Hours Due to the HOS Rule

Driver Group	Fatigue Level	Average Fatigue Risk	Percent Fatigue Level Based on Old Hours Worked	Percent Reduction in Fatigue Risk (to a Typical Driver)	Reduction in Weekly Work Time	Value of Redistribution
		A	B	C = B – A	D	E = C x D x $10.33
Moderate	Lower-bound	7%			0.28	
	Median	13%			0.28	
	Upper-bound	18%			0.28	
High	Lower-bound	7%	16.7%	9.7%	1.04	$1.04
	Median	13%	16.7%	3.7%	1.04	$0.39
	Upper-bound	18%	16.7%	-1.3%	1.04	($0.14)
Very High	Lower-bound	7%	22.3%	15.3%	3.41	$5.39
	Median	13%	22.3%	9.3%	3.41	$3.28
	Upper-bound	18%	22.3%	4.3%	3.41	$1.51
Extreme	Lower-bound	7%	29.1%	22.1%	10.70	$24.40
	Median	13%	29.1%	16.1%	10.70	$17.77
	Upper-bound	18%	29.1%	11.1%	10.70	$12.24

We next estimated the value of drivers reducing their own risk in the following week by driving less intense schedules. For this calculation, we used the average weekly work time after the HOS rule would go into effect, which was calculated earlier by subtracting the change in weekly hours worked from the average weekly work time for each group of drivers. For example, as shown in column D of Exhibit D-14 for drivers with a very high intensity schedule, this resulted in a new weekly average work time of 66.59 hours (70 hours – 3.14 hours). We then used 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 work time after the HOS rule went into effect. For example, as shown in column C of Exhibit D-14 for drivers with a very high intensity schedule, this resulted in a change in fatigue of 2.4 percent (22.3% – 19.9%). Recognizing that all hours of driving for the driver would have a lower risk of fatigue, this change in the percentage of fatigue was 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, as shown in column E of Exhibit D-14 for the very high intensity drivers, this resulted in a benefit of $16.48 per week (2.4% x 66.59 weeks x $10.33) due to the reduction of the individual driver's own fatigue level. As shown in Exhibit D-15, this calculation was repeated for each category of drivers.

Exhibit D-14. Value of Drivers Reducing Their Own Risk Due to the HOS Rule

Driver Group	Percent Fatigue Level Based on Old Hours Worked	Percent Fatigue Level Based on New Work Week	Reduction in Fatigue Risk (Own Risk)	New Average Weekly Work Time	Value of Risk Reduction
	A	B	C = A - B	D	E = $10.33 x C x D
Moderate			0.0%	44.73	$0.00
High	16.7%	15.7%	1.0%	58.96	$6.00
Very High	22.3%	19.9%	2.4%	66.59	$16.48
Extreme	29.1%	21.7%	7.4%	69.30	$52.93

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 were summed. For example, as shown in column C of Exhibit D-15 for the very high intensity drivers, this resulted in a total hourly benefit of $19.75 ($3.27 + $16.48) per week. We next converted this weekly value to an annual value by multiplying by 50 weeks of work per year. For example, as shown in column D of Exhibit D-15 for the very high intensity drivers, this resulted in an annual safety benefit of $988 ($19.75 x 50 weeks) per driver in this category. As shown in Exhibit D-15, we repeated this calculation for each category of drivers and each baseline fatigue level.

To obtain the total safety benefits for the change in weekly work time, we then multiplied the annual safety benefit per driver by the total number of drivers in each category. For example, as shown in column E of Exhibit D-16, there are an estimated 160,000 (1,600,000 drivers x 10%) very high intensity drivers. As shown in column F of Exhibit D-15, multiplying this number of drivers by the annual per driver safety benefit of $988 resulted in a total safety benefit for this category of drivers of $158 million. As shown in Exhibit D-15, this calculation was repeated for each category of drivers and each baseline fatigue level. The resulting values were summed to obtain a total safety benefit estimate of $538 million for the reduction in weekly work time for the median baseline of average fatigue risk. (This value is shown in Exhibit 6-5 of the RIA, rounded to $540 million.)

Lastly, we calculated the total safety benefits by summing the total safety benefits resulting from the change in daily driving time ($184 million) and the total safety benefits resulting from the change in weekly work time ($538 million). As shown in Exhibit D-16, this resulted in total safety benefits of $722 million under the median assumption for the percent fatigue involvement. (This value is shown in Exhibit 6-3, rounded to $720 million.)

Exhibit D-15. Total Safety Benefits for Reduction in Weekly Work Time Due to the HOS Rule

Driver Group	Fatigue Level	Value of Redistribution to a typical Driver	Value of Redistribution to Same Driver	Total Value of the Work Week Reduction (weekly)	Total Value of the Work Week Reduction (Annual)	Total Drivers	Total Safety Benefit
		A	B	C = A + B	D = C x 50 weeks	E	F = E x D
Moderate	Lower-bound					1,056,000	$0
	Median					1,056,000	$0
	Upper-bound					1,056,000	$0
High	Lower-bound	$1.04	$6.00	$7.03	$351.65	304,000	$106,900,290
	Median	$0.39	$6.00	$6.39	$319.48	304,000	$97,121,333
	Upper-bound	($0.14)	$6.00	$5.85	$292.67	304,000	$88,972,203
Very High	Lower-bound	$5.39	$16.48	$21.87	$1,093.41	160,000	$174,945,089
	Median	$3.27	$16.48	$19.75	$987.71	160,000	$158,033,403
	Upper-bound	$1.51	$16.48	$17.99	$899.63	160,000	$143,940,332
Extreme	Lower-bound	$24.39	$52.93	$77.32	$3,866.09	80,000	$309,287,054
	Median	$17.76	$52.93	$70.69	$3,534.50	80,000	$282,759,614
	Upper-bound	$12.24	$52.93	$65.16	$3,258.17	80,000	$260,653,414
Lower Bound Total							**$591,132,433**
Median Bound Total							**$537,914,350**
Upper Bound Total							**$493,565,949**

Exhibit D-16. Total Safety Benefits of HOS Rule

	Value of Weekly Work Reduction	Value of Eliminating the 11th Hour	Total Safety Benefits
	A	B	C = A + B
Lower-bound	$591	$227	$818
Median	$538	$189	$727
Upper-bound	$494	$157	$651

Health Benefits

This section presents the details of the calculation of the health benefits of the HOS rule for Option 2. The methodology is described in detail in Chapter 5. In the chapter, the calculations for the health benefits for one driver group are shown in full. This appendix provides the details for the calculations for the other driver groups.

The first step in estimating the change in expected mortality risk is to determine the hours of sleep gained under the rule. As discussed in Chapter 5, this step involves obtaining 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.

As shown in column A of Exhibit D-17, for the very high intensity group with low baseline sleep, this calculation (carried out to an appropriate level of precision) yields an estimate of 0.091 hours 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. As shown in column D of Exhibit D-17, for the very high intensity group with low baseline sleep, this calculation results in 6.371 hours (6.28 hours + 0.091 hours) of sleep per night under the Option 2. Exhibit D-17 below shows the calculations for all driver groups under all three assumptions of baseline sleep.

Exhibit D-17. Calculation of Sleep after the HOS Rule

Driver Group	Baseline Sleep	Work Hours after the Rule Change	Daily Work Hours under the Baseline	Change in Sleep	Baseline Sleep	Sleep after the Rule
		W	B	A = (-0.00138 x W^3 + 0.0235 x W^2 - 0.183 x W) - (-0.00138 x B^3 + 0.0235 x B^2 – 0.183 x B)	C	D = A + C
Moderate	Low	8.96	9.0	0.004	6.66	6.66
	Medium	8.96	9.0	0.004	7.02	7.02
	High	8.96	9.0	0.004	7.38	7.38
High	Low	9.85	10.0	0.018	6.55	6.57
	Medium	9.85	10.0	0.018	6.91	6.93
	High	9.85	10.0	0.018	7.27	7.29
Very High	Low	11.18	11.7	0.091	6.28	6.37
	Medium	11.18	11.7	0.091	6.64	6.73
	High	11.18	11.7	0.091	7	7.09
Extreme	Low	11.8	13.3	0.378	5.87	6.25
	Medium	11.8	13.3	0.378	6.23	6.61
	High	11.8	13.3	0.378	6.59	6.97

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. As described in Chapter 5, this relationship was estimated by regressing mortality on the expected value of hours of sleep and the expected value of hours of sleep squared. For example, for the very high intensity group with low sleep, this value is approximately 2.37 percent. Lastly, we used these percentages to calculate the increased life expectancy. For example, for the very high intensity group, a reduction in mortality of 2.37 percent would be associated with an increased life expectancy of 2.37 x 0.1156, or 0.2744 years. Calculations for all driver groups under all three baseline sleep assumptions are shown below in Exhibit D-18.

Exhibit D-18. Calculation of Increased Life Expectancy after HOS Rule

Driver Group	Baseline Sleep	Baseline Sleep	Sleep After the Rule	Change in Mortality from Increased Sleep	Increased Life Expectancy (years)
		B	S	A = (3.1377 x B + 0.2274 x B^2) - (3.1377 x S + 0.2274 x S^2)	C = A x 0.1156
Moderate	Low	6.66	6.66	0.04%	0.0047
	Medium	7.02	7.02	-0.02%	-0.0024
	High	7.38	7.38	-0.08%	-0.0095
High	Low	6.55	6.57	0.29%	0.0335
	Medium	6.91	6.93	-0.01%	-0.0016
	High	7.27	7.29	-0.32%	-0.0368
Very High	Low	6.28	6.37	2.37%	0.2766
	Medium	6.64	6.73	0.89%	0.1033
	High	7	7.09	-0.60%	-0.07
Extreme	Low	5.87	6.25	14.37%	1.6747
	Medium	6.23	6.61	8.19%	0.9541
	High	6.59	6.97	2.00%	0.2336

The next step in calculating the health benefits of the HOS rule is to monetize the estimated changes in mortality risk. As discussed in Chapter 5, we use the value of a statistical life (VSL) to calculate a value of a statistical life year (VSLY) of $270,670, which is the annualized value of a VSL over an individual's expected remaining years. Then, using the estimate of the years of life gained per driver for the different categories of drivers, we can estimate the value of years gained by multiplying the calculated VSLY by the years gained per driver per career. For example, as shown in column C of Exhibit D-19 for the very high intensity group with a low baseline level of sleep, this resulted in a value of years gained of $74,285 ($270,670 x 0.2744 years) per driver per career. The calculations for all driver groups for all three baseline sleep assumptions are shown in column C of Exhibit D-19.

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). As shown in column D of Exhibit D-19 for the very high intensity group with a low baseline level of sleep, this calculation yielded a gain per year of $2,122 ($74,285 / 35) in terms of reduced mortality. The calculations for all driver groups for all three baseline sleep assumptions are shown in column D of Exhibit D-19.

Finally, we calculate the total value of improvements to mortality by multiplying the value of improvement in mortality per year by the number of drivers. For example, as shown in column F of Exhibit D-19 for the very high intensity group with a low baseline level of sleep, the total value of improvements in mortality was approximately $340 million ($2,122 x 160,000 drivers). The calculations for all driver groups for all three baseline sleep assumptions are shown in column F of Exhibit D-19.

Exhibit D-19. Total Health Benefits of the HOS Rule

Driver Group	Baseline Sleep	Increased Life Expectancy (years)	VSLY	Value of years gained	Value of Improved Mortality Per Year	Number of Drivers	Total Health Benefits (Millions)
		A	B	C = A x B	D = C / 35	E	F = D x E
Moderate	Low	0.0047	$270,670	$1,272	$36	$1,056,000	$38
	Medium	-0.0023	$270,670	-$636	-$18	$1,056,000	-$19
	High	-0.0094	$270,670	-$2,544	-$73	$1,056,000	-$77
High	Low	0.0333	$270,670	$9,007	$257	$304,000	$78
	Medium	-0.0016	$270,670	-$443	-$13	$304,000	-$4
	High	-0.0365	$270,670	-$9,892	-$283	$304,000	-$86
Very High	Low	0.2744	$270,670	$74,285	$2,122	160,000	$340
	Medium	0.1025	$270,670	$27,748	$793	160,000	$127
	High	-0.0694	$270,670	-$18,788	-$537	160,000	-$86
Extreme	Low	1.6617	$270,670	$449,778	$12,851	80,000	$1,028
	Medium	0.9467	$270,670	$256,253	$7,322	80,000	$586
	High	0.2318	$270,670	$62,728	$1,792	80,000	$143
Low Baseline Sleep Total							**$1,484**
Medium Baseline Sleep Total							**$690**
High Baseline Sleep Total							**-$105**