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).

Note on data sources. Because of the recession, which started in 2008, there was a question about whether we should use post-2008 data because of the possible distorting effects of the recession. The purpose of the profile is to describe the industry as it has been and is likely to be in the future. For this reason, the most recent data we used in most cases is from 2007 or 2008. We believe this gives the most accurate picture of the industry and its operations.

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

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

- American Trucking Associations (ATA) Trucking Activity Report Historic Data Base—index of truckload vehicle miles traveled (VMT) (we used the seasonally adjusted indices for June).
- Federal Highway Administration (FHWA), Highway Statistics, 2008 and 2002, Table VM-1—VMT of combination trucks (tractor-trailers) on rural roads.
- Commodity Flow Survey (CFS) 2007 and 2002, Table 1a—ton-miles of truck freight.
- Economic Census (EC) 2007 and 2002, Transportation and Warehousing—long-distance trucking revenue (not including household goods (HHG) or packages), adjusted for price increases using Bureau of Economic Analysis (BEA) price indices for sector output.

Exhibit A-1 presents values for 2002 and 2007 and annual growth rates from 2002 to 2007.

Exhibit A-1. Annual Growth Rates – 2002 to 2007

	ATA VMT Index	FHWA VMT	CFS For-hire ton-miles	EC Revenue
2002	99.9	106,025 million	959.6 billion	$117.3 billion
2007	91.8	103,208 million	1,055.6 billion	$135.2 billion
Growth rate	-1.7 percent	-0.5 percent	1.9 percent	2.9 percent

Nominal revenue was $160.7 billion in 2007. To obtain the growth rate, it was necessary to adjust for inflation. The 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
2007 index: 123.8
$160.7 billion x 104.2 / 123.8 = $135.2 billion

2. Revenue

The for-hire revenue estimate of $160.7 billion in 2007 is based on two different data sources published by the U.S. Census Bureau. The Census Bureau gathers data from firms with employees through its surveys, and these data—reasonably reliable sources for revenue of carriers with payrolls—are published every five years in the EC. The EC reports separately on:

- General freight, long-distance, truckload (NAICS 484121)
- General freight, long-distance, LTL (NAICS 484122)
- Specialized freight, long-distance (except HHG) (NAICS 48423)

The EC defines specialized freight as freight requiring special equipment—primarily refrigerated vans, tank trailers, and flatbed trailers. The overall definition also includes carriage of HHG.

The EC surveys, however, do not provide any information on the revenues of owner-operators. In a separate effort, the Census uses a sampling of individual income-tax returns to collect data on non-employer firms and publishes the results annually. Data based on tax returns of individuals may well be more prone to error than data obtained from survey forms filled out by firms with staffs. A filer preparing Schedule C of Form 1040 is given three choices for type of trucking business:

- General freight, local (NAICS 48411)
- General freight, long distance (NAICS 48412)
- Specialized freight (NAICS 4842)

The choice between local and long distance is a problem. The instructions for Schedule C provide no guidance on the definition of local and long distance.[1] There is every reason to believe that a large number of filers who identified themselves as long-distance are, in fact, local (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. ICF's analysis of the 2002 Vehicle Inventory Use Survey (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.[2] 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. And an analysis of VIUS data done by OOIDA indicates that over half of owner-operators own no tractors.[3] For general freight, the Census non-employer data show approximately 33.0 percent of revenue from short-haul service and 67.0 percent from long-haul. In light of the distribution of trucks and tractors between long and short-haul, it is difficult to accept this pattern.

ICF determined that 33.5 percent is a reasonable estimate of the percentage of owner-operators that are in long-haul service. (Details of this estimate are in a subsequent section on estimate

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[1] Internal Revenue Service, Instructions for Schedule C, Retrieved August 4, 2010 from: http://www.irs.gov/pub/irs-pdf/i1040sc.pdf
[2] VIUS was not conducted in 2007, so the 2002 data are the most recent source of information on ownership and truck characteristics.
[3] John Siebert, "OOIDA Analysis of the 2002 VIUS to Determine the Owner-Operator Role in the American Trucking Industry," OOIDA Foundation, April 2005

of number of owner-operators.) We may use this percentage to estimate revenue for non-employer, long-distance firms carrying general freight.

Specialized freight is a different problem, for it includes local and long-distance service and HHG. We address this problem by first removing HHG from non-employer specialized freight and then applying 33.5 percent to the remainder to obtain non-employer revenue for long-distance, non-HHG, specialized freight.

We remove HHG, because we do not include either HHG or carriage of packages in the revenue estimate. In both of these sectors, a very high proportion of cost is incurred in local pick-up and delivery, such that these revenues are not comparable with revenue from OTR service in other sectors.

Specialized freight for employer firms:

All specialized freight (NAICS 4842): $75.617 billion
HHG (NAICS 48421): $14.384 billion

14.384 ÷ 75.617 = 0.190
1 – 0.190 = 0.810, non-HHG specialized freight

All specialized freight for non-employer firms: $4.111 billion.

0.810 x 4.111 = $3.329 billion, non-HHG, non-employer, specialized firms

0.335 x 3.329 = $1.115 billion, long-distance, non-HHG, non-employer specialized firms

We need to address one more issue with revenue of non-employer firms. We have no way of knowing whether these firms are leased owner-operators or owner-operators working as independents under their own authority. If they are leased owner-operators, their revenue is payments from the larger firms to which they are leased. This revenue is already counted in the revenue reported by employer firms. We should add only the revenue of independent owner-operators. There are data from OOIDA that indicate approximately 30.0 percent of their members are independents.[4]

0.30 x 1.115 = $0.335 billion.

This is the revenue generated by independent, non-employer, specialized trucking firms.

The non-employer data indicate revenue for long-distance, general freight of $29.553 billion. We must also multiply this figure by 0.30 to obtain the revenue generated by independent firms.

0.30 x 29.553 = $8.866 billion.

This is the revenue generated by independent, non-employer, general-freight trucking firms.

Exhibit A-2 summarizes the revenue estimate for long-distance, for-hire carriers (excluding package carriers and HHG carriers).

[4] http://www.ooida.com/OOIDA%20Foundation/Recent_Research/OOIDP-08.html, retrieved 6/23/11.

Exhibit A-2. Long-distance, For-hire Revenue (excluding package and HHG carriers)

Type of carrier	Revenue (billions)
Employer firms	
Truckload	$83.471
Less-than-truckload	$37.659
Specialized freight	$30.322
Non-employer firms	
General freight	$8.866
Specialized freight	$0.335
Total	**$160.652**

3. Number of Drivers

To estimate the number of drivers, we use our revenue estimates for long-distance truckload service and LTL service to obtain numbers of tractors in those sectors. From that point, we develop number of tractors in other sectors and use driver-per-power-unit ratios to obtain number of drivers. Truckload revenue per tractor per year—$160,000—was obtained in off-the-record discussions with ICF's industry contacts. We heard estimates in the range of $160,000 to $175,000 per year. We chose the low end of the range to avoid understating the impact of the rule. A higher revenue number would lead to fewer tractors and drivers and a lower estimate of the impact.

Estimate of LTL revenue per tractor per year is based on data from the 2008 National Motor Carrier Directory (NMCD) (largely 2007 data). Driver-per-power-unit ratios were derived from FMCSA's 2007 SAFER data.

For LTL revenue per tractor, we used NMCD data for the following firms (before Yellow/Roadway merger). (These are the LTL firms found in the 2009 Transport Topics Top 100 For-hire Carriers.)

- Con-way Freight
- ABF
- Yellow
- Roadway
- Old Dominion
- NEMF
- Southeastern
- Roadrunner
- AAA Cooper
- Estes
- SAIA
- Averitt
- Pitt Ohio
- Central Freight
- A. Duey Pyle

Total reported revenue for these companies was $19,259 billion; tractors owned or leased: 58,750.

$19.26 billion ÷ 58,750 = $327,818

We round this to $328,000 for the purpose of the estimate.

Key numbers:

Truckload revenue per tractor per year:	$160,000
LTL revenue per tractor per year	$328,000
Truckload drivers per power unit:	1.13
LTL drivers per power unit:	1.36

From our estimate of for-hire revenue, we have truckload revenue of $122.933 billion.

122.933 billion ÷ 160,000 = 768,709 tractors
768,709 x 1.13 =867,268 truckload drivers

From our estimate of for-hire revenue, we have LTL revenue of $37.659 billion.

37.659 billion ÷ 328,000 = 114,814 tractors
114,814 x 1.36 = 155,876 LTL drivers

867,268 + 155,876 = 1,023,144 for-hire drivers

To estimate the number of private drivers, we used data on number of for-hire and private tractors from the 2002 VIUS.[5] These data show private tractors as 61.7 percent of for-hire tractors (including owner-operators), including tractors in both local and OTR service. Further calculations based on these data show that OTR private tractors are 37.0 percent of OTR for-hire tractors.[6] We have 768,709 truckload tractors and 114, 814 LTL tractors.

768,709 + 114,814 = 883,523 for-hire tractors
0.37 x 883,523 = 331,036 private tractors

For driver per power unit, we use 1.25—midway between truckload and LTL.

1.25 x 331,036 = 413,795 private drivers

We also need to estimate drivers for HHG carriers and package carriers. The HHG trade association—American Moving and Storage Association (AMSA) reports in its fact sheet that its members operate 18,000 straight trucks and 32,000 tractors.[7] The 2007 Economic Census reports that long-distance moving (NAICS 4842102) accounts for 69.7 percent of revenue from all HHG carriage (NAICS 48421). We assume, then, 70.0 percent of the reported 50,000 trucks

[5] Census Bureau, 2002, Economic Census, Vehicle Inventory and Use Survey, Table 5, p. 44

[6] Analysis by ICF in 2008, based on unpublished VIUS outputs, provided distribution of both private and for-hire tractors across ranges of operation.

[7] American Moving and Storage Association, "Industry Fact Sheet," May 2010

are in long-distance service, most of them tractors. Many HHG trucks will have two people in the cab, and they often share driving duties. So we assume a driver/power unit ratio of 1.75.

0.70 x 50,000 = 35,000 HHG long-distance trucks
35,000 x 1.75 = 61,250 HHG long-distance drivers

For package carriers, we base the estimate on revenue per tractor of UPS and FedEx and on total revenue from ground package carriage. Main data sources are:

- 2009 Transport Topics Top 100 For-hire Carriers—for UPS and FedEx tractors
- SEC Form 10-Ks for UPS and FedEx—revenue from ground operations
- 2007 Economic Census—total revenue from non-air package carriage (NAICS 4921101)

The 2009 Transport Topics Top 100 reports, for 2008, 18,740 company tractors for UPS. For FedEx, it reports 15,000 company tractors; it also reports 22,000 owner-operator tractors, straight trucks, and vans. Ground revenue of UPS in 2008 was roughly double that of FedEx. For that reason, it is not plausible that FedEx would have as many tractors as UPS. Accordingly, we disregard the owner-operator number and accept only the number for company tractors. The result is 33,740 tractors for the two large package carriers.

In their Forms 10-K, UPS and FedEx report revenue by type of service. Both operate ground-package services and both operate freight-trucking services. We took the 2008 revenues from these sources as their ground revenue—$23.585 billion for UPS, $11.685 billion for FedEx, total of $35.270 billion.

We divide combined UPS and FedEx ground revenue by number of tractors.

35.270 billion ÷ 33,470 = $1,053,700, revenue per tractor

2007 Economic Census reports revenue from non-air package service as $44.042 billion.

44.042 billion ÷ 1,053,780 = 41,794 tractors in non-air package service

We use the LTL driver/power-unit ratio of 1.36.

1.36 x 41,794 = 56,742 OTR drivers for package companies.

Exhibit A-3 summarizes the estimate of number of drivers.

Exhibit A-3. Number of OTR Drivers

Sector	Drivers
Truckload	867,268
LTL	155,876
Private	413,795
Household goods	61,250
Ground packages	56,742
Total	**1,554,930**

We estimate 1.554 million OTR drivers.

4. Vehicle Miles Traveled

The estimate of vehicle miles traveled (VMT) is based on our estimate of 768,609 tractors in truckload service. Using an industry standard of approximately 100,000 miles per tractor per year in OTR service, we obtain truckload VMT of 76.871 billion. We obtain LTL VMT on the basis of our estimate that LTL VMT is approximately 17.0 percent of truckload VMT.

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

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 A-4.

Exhibit A-4. Less-than-Truckload and Truckload Vehicle Miles Traveled 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.

On this basis, LTL VMT is 15.7 billion.

0.17 x 76.871 = 15.7 billion

76.871 billion + 15.7 billion = 92.6 billion for-hire VMT

The next step is to estimate private OTR VMT. As noted above, we estimated 331,036 private tractors in OTR service. Calculations based on the 2002 VIUS show annual miles per private tractor of approximately 40,000. This includes both local and OTR service. Average miles per tractor per year will necessarily be higher when considering only OTR service, but it will not be as high as the 100,000 annual miles for a for-hire tractor in OTR service. We assume 60,000 miles per year for the average OTR private tractor.

331,036 x 60,000 = 19.9 billion

92.6 billion + 19.9 billion = 112.5 billion VMT

5. Number of Truckload Firms

Estimating the number of truckload firms was a somewhat complex process. We developed an estimate of approximately 65,000 long-haul for-hire firms in 2007 using the following data sources:

- EC 2007
- 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 do not. While the EC data on firms with employees seem reliable, there are question about how to interpret the EC data on non-employee firms.

The starting point for the estimate is the 2007 EC data on long-haul carriers with employees.[8] The relevant data are those for the types of carriers shown in Exhibit A-5. General freight and household goods are self-explanatory. Specialized freight is cargo moving on flatbeds, in tank trailers, or in refrigerated trailers.[9]

Exhibit A-5. Long-haul Truckload Firms in 2007 Economic Census

Type of Carrier	NAICS Code	Firms
General Freight	484121	24,648
Specialized Freight	48423	8,025
Total		**32,672**

NOTE: Number of firms is adjusted for firms in operation less than one year.
NAICS 48423 is all long-haul specialized freight except HHG.

6. Question of Firms in Operation less than 1 Year

The data above had to be adjusted to allow for firms in operation for less than a full year in 2007. Of the firms reported in these categories, 7,754 were in operation for less than 1 year, 21 percent of all the firms reported for 2007. The comparable percentage for the 2002 EC is 26 percent, which suggests some stability in the relative size of this group.

If we included all of the short-term firms in our base number, the result would be an over-estimate of the number of firms in operation at any given time. It is clear that a downward adjustment had to be made. For this analysis, we assumed that the average short-term firm is in operation for 6 months in the year in question; therefore, we reduced the total by one-half of

[8] U.S. Census Bureau, 2002 Economic Census, Transportation and Warehousing—Subject Series, Table 4.
[9] 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.

7,754 to obtain the numbers in the table above. These are the long-distance, truckload firms with employees in 2007. To complete the estimate, we need to add carriers without employees.

7. 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: the OOIDA analysis of the 2002 VIUS and the EC data on non-employer firms.[10]

The EC data on non-employer firms presented in Exhibit A-6 show 296,060 firms for long-distance general freight in 2007 and 193,146 firms in local general freight. Also, these data show 53,303 such firms in specialized trucking but do not break specialized service between long-haul and short-haul. This is all specialized freight and includes HHG.

Exhibit A-6. Non-employer Firms 2007 Economic Census

General freight long-distance	296,060
General freight local	193,146
Specialized freight	53,303
Total	**542,509**

The OOIDA VIUS data show about 543,000 power units owned by owner-operators in 2002. Since the OOIDA VIUS data include some owner-operators with more than one vehicle, they include some employer firms and total number of firms must be somewhat less than 546,000, Nonetheless, these data sources are roughly consistent with each other. Earlier data also show a large number of owner-operators of all types. In a 1998 study, University of Michigan Professor Francine Lafontaine estimated that there were 320,000 owner-operators.

ICF's further analysis of VIUS data reveal, however, that the 500,000 power units shown in the OOIDA VIUS 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 EC data on non-employer firms are drawn from Federal income-tax returns in which the absence of

[10] U.S. Census Bureau, "2002 Economic Statistics: Non-Employer Statistics Transportation and Warehousing United States." http://www.census.gov/epcd/nonemployer/2002/us/US000_48.HTM
U.S. Census Bureau, Non-Employer Statistics 2007: Transportation and Warehousing United States. http://www.census.gov/epcd/nonemployer/latest/us/US000_48.HTM

employees is clear. A trucking firm without employees must be an owner-operator (although some owner-operators have employees). In the EC data, 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 local and long-distance 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.[11]

As noted earlier, 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. ICF's analysis of VIUS shows that five percent of for-hire straight trucks are in long-distance service, and 62 percent of for-hire tractors are in long-distance 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. And the OOIDA VIUS data indicate that over half of owner-operators own no tractors. Setting aside specialized freight, the EC non-employer data show approximately 40.0 percent of firms 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 OOIDA VIUS data, we can extract an estimate of the number of straight trucks and tractors owned by owner-operators: 119,000 straight trucks and 117,000 tractors, 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 approximately 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 who (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 2007.

Exhibit A-7 shows the chain of calculations that leads to the estimate of non-employer firms.

[11] Internal Revenue Service, Instructions for Schedule C, Retrieved August 4, 2010 from: http://www.irs.gov/pub/irs-pdf/i1040sc.pdf

Exhibit A-7. Non-employer Firms

Total from 2007 non-employer data	540,000
Exclusion of vehicles <10,000 lbs.	325,000
Independent owner-operators	97,500 (0.3 x 325,000)
Independent O-Os 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 Census data for firms with employees.

We add our estimate of independent owner-operators in long-haul service to employer firms in long-distance, truckload service.

32,672 + 32,500 = 65,172 long-distance, truckload firms.

8. Size Distribution

Principal data sources are:

- EC 2007
- FleetSeek National Motor Carrier Directory (NMCD) 2008 edition (2007 or later data).
- American Trucking Associations (ATA) For-Hire Fleet Directory 2008 edition (2005-2007 data).

As shown in Exhibit A-8, both the NMCD and ATA's directory capture significant fractions of the employee firms reported in the 2007 EC—about 25 percent for the ATA directory and 43 percent for the NMCD. 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 as to be mutually corroborating. We see this in the following table showing distribution for firms with more than five tractors.

Exhibit A-8. Size distribution of For-hire Firms

	NMCD		ATA	
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 data base is the larger, 44,000 firms (including those with 1–5 tractors) against 25,000 in ATA's directory, we use it as the basis for estimating size distribution. The 44,000 firms in the NMCD data are 43 percent of the just over 100,000 firms reported in the 2007 EC, 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 percentages as reliable for firms with six or more tractors. The distribution for all firms in the NMCD data, including the one-to-five class is shown in Exhibit A-9.

Exhibit A-9. Size Distribution for all Firms from NMCD Data

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 make 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 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 38 percent (including short-time firms). This brings us to 9,018 firms in this size class. We then use, as an expansion factor, 0.47, the ratio of the NMCD population to the EC population of employer firms (adjusted for short-time firms) and obtain 19,384 employer firms in this size class. To this we add our estimate of 32,500 non-employer long-haul firms for a total of 51,884 long-haul firms in the one-to-five class. Exhibit A-10 shows the chain of calculations.

Exhibit A-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	9,018 *(0.38 x 23,710)*
EcCen employer firms in 1–5	19,384 *(9,018 ÷ 0.47)*
All firms in 1–5	51,884 *(19,384 + 32,500)*

All firms with more than five tractors are taken to be employer firms. Therefore, we subtract the 19,384 employer firms in the one-to-five class from our estimate of 32,672 long-haul employer firms and obtain 13,288 firms with more than five tractors. We distribute these firms over the higher size classes using the NMCD percentages shown above. The result is shown in Exhibit A-11.

Exhibit A-11. Distribution of Firms by Class Size

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

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 B-1) from a database of 64,000 drivers complied by RoadReady:

Exhibit B-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 B-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 B-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

Section 1

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 B-3 presents the results of the quantitative analysis of the Ferrie et al. 2007 data:

Exhibit B-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 B-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 B-4 reflects current thinking on how this network of relationships acts on human health:

Exhibit B-4. Health habit and risk relationships

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

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

Table of Contents

List of Exhibits

Appendix C

1. 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: 10 hours of driving allowed per day, 9 hours of driving allowed per day, the 7-day restart restriction, the 2-night restart provision, and the 30-minute break provision. 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 due to the 30-minute break provision is expected to reduce the use of the 11th 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.*

2. 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 5 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 provision, and 30-minute break provision. Option 2 imposes 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 $5.1 billion. The next largest cost component is the 7-day restart restriction, which equals $2.6 billion.

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

10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Provision	30-Minute Break Provision
$5,100	$15,900	$2,600	$400	$700

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

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

	10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Provision	30-Minute Break Provision
Low Sleep	$6,500	$15,300	$5,900	$800	$1,700
Medium Sleep	$4,700	$10,300	$4,100	$500	$1,300
High Sleep	$2,800	$5,300	$2,300	$300	$800

Exhibit C-3 displays the discounted net benefits broken down into the various components. When we use the medium baseline sleep assumption, the 7-day restart restriction shows the largest net benefits at $1.5 billion. The second largest net benefits are those resulting from the 30-minute break provision, which amounts to approximately $500 million. Assuming low baseline sleep, the 7-day restart restriction is again the largest net benefit at approximately $6.5 billion. The net benefits become negative for the 9-hour driving restriction under the medium and high baseline sleep scenarios, amounting to negative $5.9 billion and negative $10.9 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)

	10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Provision	30-Minute Break Provision
Low Sleep	$1,400	-$900	$3,300	$400	$1,100
Medium Sleep	-$500	-$5,900	$1,500	$200	$500
High Sleep	-$2,300	-$10,900	-$200	-$100	$100

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)

10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Provision	30-Minute Break Provision
$6,000	$18,600	$3,000	$400	$800

Exhibit C-5 presents the discounted benefits of the proposed option broken down into the five components. Using a discount rate of 3 percent, the 9-hour driving restriction results in the largest benefits ($20.9 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 $13.0 and $5.1 billion, respectively.

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

	10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Provision	30-Minute Break Provision
Low Sleep	$9,000	$20,900	$8,600	$1,100	$2,500
Medium Sleep	$6,000	$13,000	$5,800	$800	$1,800
High Sleep	$3,100	$5,100	$3,000	$400	$1,000

Exhibit C-6 displays the discounted net benefits broken down into the five components. When we use the medium baseline sleep assumption, the 7-day restart restriction results in the largest net benefits - approximately $2.8 billion. When we use the low baseline sleep assumption, the 7-day restart restriction again shows the largest net benefits at approximately $5.5 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, the 9-hour driving restriction, and the 2-night restart provision result in net benefits equal negative $2.9 billion, negative $13.4 billion, and negative $100 million, respectively. We obtained a similar result for the 9-hour driving restriction using the medium baseline sleep scenario, with net benefits amounting to negative $5.5 billion.

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

	10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Provision	30-Minute Break Provision
Low Sleep	$3,000	$2,400	$5,500	$700	$1,700
Medium Sleep	$0	-$5,500	$2,800	$300	$1,000
High Sleep	-$2,900	-$13,400	$0	-$100	$200

To compare these component net benefits across the options, we can sum the individual components of Options 2 through 4. Because all the options include the 7-day restart restriction, the 2-night restart provision, and the 30-minute break provision, we can compare the differences for these options by considering the driving time restrictions alone. Because 11 hours are allowed under the current rule, the benefits for Option 3 represent the base case (i.e., no incremental net benefits beyond the 7-day restart restriction, the 2-night restart provision, and the 30-minute break provision). Option 2 restricts driving time to 10 hours, resulting in incremental net benefits of $3.0 billion for the low sleep scenario, zero for the medium sleep scenario, and negative $2.9 billion for the high sleep scenario. 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 $2.4 billion, negative $5.5 billion, and negative $13.4 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)

10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Provision	30-Minute Break Provision
$680	$2,120	$340	$50	$90

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

	10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Provision	30-Minute Break Provision
			7% Discounting		
Low Sleep	$870	$2,040	$780	$110	$230
Medium Sleep	$620	$1,370	$550	$70	$140
High Sleep	$370	$710	$310	$40	$100
			3% Discounting		
Low Sleep	$1,020	$2,380	$980	$130	$290
Medium Sleep	$680	$1,480	$660	$90	$200
High Sleep	$350	$580	$340	$40	$110

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

	10-Hour Driving Restriction	**9-Hour Driving Restriction**	**7-Day Restart Restriction**	**2-Night Restart Provision**	**30-Minute Break Provision**
			7% Discounting		
Low Sleep	$190	-$120	$440	$50	$140
Medium Sleep	-$60	-$780	$200	$20	$70
High Sleep	-$310	-$1,450	-$30	-$10	$10
			3% Discounting		
Low Sleep	$340	$270	$630	$80	$190
Medium Sleep	$0	-$630	$320	$30	$110
High Sleep	-$330	-$1530	$0	-$10	$20

Next, we present the results of the analysis broken down into components 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 options 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.

3. 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)

10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Provision	30-Minute Break Provision
$5,100	$15,900	$2,600	$400	$700

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

	10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Provision	30-Minute Break Provision
Low Sleep	$5,000	$11,600	$5,100	$700	$1,500
Medium Sleep	$3,200	$6,600	$3,300	$500	$1,000
High Sleep	$1,300	$1,700	$1,600	$200	$500

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

	10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Provision	30-Minute Break Provision
Low Sleep	-$100	$4,600	$2,300	$300	$800
Medium Sleep	-$2,000	-$9,600	$800	$100	$200
High Sleep	-$3,800	-$14,600	-$1,100	-$200	-$200

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

10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Provision	30-Minute Break Provision
$6,000	$18,600	$3,000	$400	$800

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

	10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Provision	30-Minute Break Provision
Low Sleep	$7,300	$16,600	$7,600	$1,000	$2,200
Medium Sleep	$4,300	$8,700	$4,800	$600	$1,500
High Sleep	$1,300	$800	$2,000	$300	$700

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

	10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Provision	30-Minute Break Provision
Low Sleep	$1,300	-$2,000	$4,700	$500	$1,400
Medium Sleep	-$1,700	-$9,800	$1,800	$200	$600
High Sleep	-$4,700	-$17,700	-$100	-$200	-$200

Exhibit C-16. Annual Costs by Rule Component (Millions)

(Excludes approximately $40 million for training and reprogramming)

10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Provision	30-Minute Break Provision
$680	$2,120	$340	$50	$90

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

	10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Provision	30-Minute Break Provision
			7% Discounting		
Low Sleep	$670	$1,550	$680	$90	$200
Medium Sleep	$420	$880	$440	$60	$130
High Sleep	$170	$220	$210	$20	$70
			3% Discounting		
Low Sleep	$830	$1,890	$870	$110	$250
Medium Sleep	$490	$990	$550	$70	$170
High Sleep	$150	$90	$230	$30	$80

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

	10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Provision	30-Minute Break Provision
			7% Discounting		
Low Sleep	-$10	-$610	$300	$40	$100
Medium Sleep	-$260	-$1,280	$100	$10	$40
High Sleep	-$560	-$1,940	-$140	-$30	-$30
			3% Discounting		
Low Sleep	$150	-$230	$530	$60	$160
Medium Sleep	-$190	-$1,120	$210	$20	$70
High Sleep	-$530	-$2,020	-$110	-$20	-$20

4. 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)

	10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Provision	30-Minute Break Provision
Low Sleep	$770	$18,400	$6,500	$900	$2,000
Medium Sleep	$590	$13,400	$4,700	$700	$1,400
High Sleep	$400	$8,400	$3,000	$400	$1,000

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

	10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Provision	30-Minute Break Provision
Low Sleep	$2,600	$2,200	$4,000	$500	$1,200
Medium Sleep	$800	-$2,900	$2,200	$300	$800
High Sleep	-$1,100	-$7,800	$500	$0	$300

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

	10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Provision	30-Minute Break Provision
Low Sleep	$8,900	$12,000	$8,000	$1,100	$2,300
Medium Sleep	$6,400	$14,200	$5,600	$800	$1,700
High Sleep	$3,800	$7,400	$3,200	$500	$1,100

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

	10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Provision	30-Minute Break Provision
Low Sleep	$3,800	$500	$5,400	$700	$1,700
Medium Sleep	$1,300	-$1,700	$3,000	$400	$1,000
High Sleep	-$3,100	-$8,400	$700	$0	$400

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

	10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Provision	30-Minute Break Provision
			7% Discounting		
Low Sleep	$1,030	$2,450	$870	$120	$260
Medium Sleep	$780	$1,780	$630	$90	$190
High Sleep	$530	$1,120	$400	$50	$130
			3% Discounting		
Low Sleep	$1,180	$2,797	$1,060	$140	$130
Medium Sleep	$850	$1,890	$750	$100	$230
High Sleep	$510	$990	$430	$60	$140

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

	10-Hour Driving Restriction	9-Hour Driving Restriction	7-Day Restart Restriction	2-Night Restart Provision	30-Minute Break Provision
			7% Discounting		
Low Sleep	$350	$290	$530	$70	$160
Medium Sleep	$100	-$380	$290	$40	$100
High Sleep	-$150	-$1,040	$60	$0	$40
			3% Discounting		
Low Sleep	$500	$670	$720	$90	$220
Medium Sleep	$170	-$220	$400	$50	$130
High Sleep	-$170	-$1120	$90	$0	$50

5. Rule Components, Packages, and Interaction Effects

Exhibit C-25 extends the single component analysis and compares the individual component costs, benefits, and net benefits for the 7-day restart provision, the 2-night restart provision, and the 30-minute break provision independently, for packages of two of the three provisions, and for all three provisions. First, we considered the selected provisions separately with no overlapping effects. Next, we considered the provisions in packages of two, including overlapping effects. Finally, we compared the two methods to estimate the interaction effect of each grouping of the rule components. We round the values in Exhibit C-25 to the nearest million to demonstrate the similarity in net benefits for some of these alternatives.

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

Exhibit C-25. Component and Interaction Costs, Benefits and Net Benefits (Millions 2008$)

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

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

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

1. 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 (where relevant) 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 of the rule provisions for Option 2 on the existing patterns of work, we divided the provisions into three distinct effects: the effect of the 30-minute break provision, 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 impacts of the 30-minute break provision for Option 2, we used industry data to allocate the use of the last hour of the workday because the need to take a break will cut into the ability of drivers to use the entire 14-hour window. It is estimated that 9 percent of drivers use the 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 the 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 impact of the 30-minute break provision on the working day in terms of productivity, we assume that a portion of the lost work time is redistributed to other, less-intense workdays. 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 workdays. We assume that the moderate intensity driver is unaffected by this change because they are not typically driving in the 14th hour, and if they were they would have the flexibility in their schedule to shift the 30 minutes to another day. We assume the high intensity driver uses 1/2 of those 30 minutes already as a break and would shift 1/2 of the remaining 15 minutes to another day. The very high intensity driver is assumed to be using 1/4 of the 30 minutes as a break in the base case (assuming 3/4 of the 30 minutes used in the baseline) and shifts 1/3 of the remaining time to another day (1/3 of 1/4 of 0.50 hour). Finally, for the extreme intensity driver, we assume that no time was devoted to breaks in the baseline, and that no time can be shifted to another day. Thus, the extreme intensity drivers lose a full 30 minutes when they are required to take a break.

To calculate the productivity impact, we multiplied the percent of trips that use the 14th hour by the 30-minute required break, adjusted by a factor reflecting the time already assumed to be devoted to breaks, and then multiplied 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 0.54 percent loss in productivity per day ([25% x 0.50 hour x 0.75 hour x 2/3] / 11.7 hours). We also calculate the hours lost per week per driver group, which is the loss per day multiplied 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 0.38 hours lost a week (25% x 0.50 hour x 0.75 hour 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 Due to the 30-minute Break Provision

Driver Group	Percent of Trips that Use the 14th Hour of Work	Percent of 14th Hour Used in Baseline	Portion of Affected Time Lost Rather Than Shifted	Average Number of Hours Worked Per Day	Days Expected to Work in a Week	Unweighted Productivity Impact	Hours Lost Per Week - 30-Minute Break Provision
	A	B	C	D	E	F = (A x B x C x 0.5) / D	G = A x B x C x E x 0.5
Moderate	2%	0	0	9.0	5	0.00%	0.00
High	7%	½	½	10.0	6	0.09%	0.05
Very High	25%	¾	2/3	11.7	6	0.54%	0.38
Extreme	60%	1	1	13.3	6	2.25%	1.80

We next calculate the productivity lost due to the shift from an 11- to a 10-hour driving day for Option 2. These calculations parallel the 30-minute break provision 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 hour / 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 hour x 6 days). Exhibit D-2 summarizes these assumptions and calculations for each of the driver groups.

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 workday 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 0.07 percent for reduction in daily work time (13.4% x 0.54%) 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

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 Rather Than Shifted	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

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

Driver Group	Percent of Work Effort	Unweighted Productivity Impact – 30-Minute Break Provision	Weighted Productivity Impact – 30-Minute Break Provision	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%	0.00%	0.79%	0.45%	0.45%
High	21.90%	0.09%	0.02%	2.03%	0.44%	0.43%
Very High	13.40%	0.54%	0.07%	4.17%	0.56%	0.52%
Extreme	7.70%	2.25%	0.17%	5.95%	0.46%	0.37%

for the very high intensity driver group, this calculation resulted in an adjusted weighted productivity loss of 0.52 percent (0.56% - [50% x 0.07%]). 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.

The last step of estimating the operational costs was to calculate the cost of the changes to the restart provision. Currently, this provision allows drivers to restart their workweek if they take a break of at least 34 hours. Options 2, 3, and 4 make two changes to this provision. First, it will have to include two periods from 1:00 AM to 5:00 AM; this change is termed the “2-night restart provision.” Second, the restart can be used to extend working hours only once every 7 days; this change is termed the “168-hour rule.” The restart provision only affects drivers who work 60 hours or more, and thus only affects the very high and extreme intensity driver groups.

To estimate the effect of the restart provision for Option 2, 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 2.11 hours lost per week (2.25 hours – 50% x [0.37 hour 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 - 30-Minute Break Provision	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	0.28	7.0	9.00	0.28
High	0.05	0.98	8.0	10.00	0.95
Very High	0.37	2.25	9.0	11.67	2.11
Extreme	1.80	3.57	10.0	13.33	2.90

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. The 2-night restart provision was estimated to reduce available work hours by an average of 0.5 hour for the very high and extreme intensity groups, based on distributions of stopping and starting hours for drivers using the restart provision (details of these calculations are presented in Appendix E). For the very high intensity drivers, the total hours lost per week due to both changes in the restart provision was assumed to be limited to the 0.5-hour impact of the 2-night restart provision. The other change, the 168-hour rule, would not affect these drivers because, using the restart once every 168 hours, they will still be able to work an average of 70 hours per week, and thus their weekly work time will not be reduced. For the extreme intensity group of drivers, on the other hand, the 168-hour rule will bring their workweek down to only 70 hours, and then the 2-night restart provision can be assumed to have an additional impact of 0.5 hour per week. To avoid double-counting the effects of changes in other provisions, the impact of the restart provision was determined by taking the average hours worked per week for the extreme intensity group (80 hours) and subtracting the hours lost due to the restrictions in daily work time (1.80 hours) and the hours lost due to the restriction in daily driving time (2.90 hours) minus 70 hours, which is allowed under the new restart provisions. As shown in column A of Exhibit D-5, the loss of 0.5 hour per week due to the 2-night restart provision was added to this number, to arrive at a total of 5.81 hours ([80 hours – 1.80 hours – 2.90 hours – 70 hours] + 0.50 hour) lost per week due to the new restart provision for the drivers with extremely intense schedules.

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%	0.00%
High	0	60	21.90%	0.00%
Very High	0.50	70	13.40%	0.10%
Extreme	5.81	80	7.70%	0.56%

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 5.81 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 0.56 percent (5.81 hours / 80 hours x 7.7%) of lost productivity for this group of drivers due to the new restart provisions. We performed a similar calculation for the drivers with very high intensity schedules. Exhibit D-5 below shows these calculations.

The next step was to monetize these changes in productivity due to the three major changes resulting from the HOS rule provisions for Option 2. 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 1.78% (0.45% for moderate intensity drivers + 0.43% for high intensity drivers + 0.52% for very high intensity drivers + 0.37% 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 $633.25 million (1.78% 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 – 30-Minute Break Provision	Weighted Productivity Impact – 11th Hour Driving (With Double Counting Adjustment)	Weighted Productivity Impact - Restart Provision
Moderate	0.00%	0.45%	0.00%
High	0.02%	0.43%	0.00%
Very High	0.07%	0.52%	0.10%
Extreme	0.17%	0.37%	0.56%
Total Productivity Loss	**0.26%**	**1.78%**	**0.65%**
Total Cost - $356 Million Per 1% (Millions)	**$94.03**	**$633.25**	**$232.72**

Lastly, we estimated the total productivity lost in terms of hours per week for Option 2. As shown in column D of Exhibit D-7, the total productivity lost for the very high intensity driver group was 2.98 hours. This is calculated by summing across the 3 types of rule provisions discussed above, including 0.38 hours lost due to the 30-minute break provision, 2.11 hours lost due to the reduction in the daily driving time, and 0.50 hour 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 – 30-Minute Break Provision	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	0.05	0.95	0	1.01
Very High	0.38	2.11	0.50	2.98
Extreme	1.80	2.90	5.81	10.50

2. 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 provisions for Option 2 can be broken down into two effects: the benefits of the restriction on daily driving time, and the benefits of reducing cumulative hours worked per week. As discussed in Chapter 4, the number of affected 11th hours per week can 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 per week (25% x 1 hour x 6 tours) 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.

Exhibit D-8. Driving Time Lost (or 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	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 or Shifted							**90,000,000**

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 workday) 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.

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 driver 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	Hours Affected per Year per Driver, Weighted	Percent of Hours Shifted Rather Than Lost	Hours Shifted per Year per Driver, Weighted
	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 (36.15 percent) minus the average percent fatigue involvement for all other hours (13.00 percent), or 23.15 percent (36.15% - 13.00%). 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 $2.66 (23.15% x $11.49) per hour of the change in fatigue risk from removing the 11th hour when the restricted driving is reallocated to another driver. We also calculated this value for 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	12.5%	7.7%	$11.49	$1.43	$0.88
Median	23.1%	14.2%	$11.49	$2.66	$1.63
Upper-bound	32.1%	19.7%	$11.49	$3.68	$2.26

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 (36.15 percent) minus the average percent fatigue involvement for hours 6 through 10 (21.92 percent), or 14.23 percent (36.15% - 21.92%). We next 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 $1.63 (14.23 % x $11.49) per hour of the change in fatigue risk from removing the 11th hour when the restricted driving is redistributed to other days by the same driver. Similar calculations were made using the upper- and lower-bound fatigue levels.

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 ($2.66) by the assumed percent of hours for this scenario (68%) and the value per hour for hours that are shifted to another driver ($1.63) 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 $2.34 ([$2.66 x 68%] + [$1.63 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 $210 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.

Next, we estimated the safety benefits due to the change in weekly work time for Option 2. 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 (2.98 hours) was subtracted from their average weekly work time (70 hours) to obtain a new average weekly work time of just above 67 hours. As shown in Exhibit D-12, this calculation was repeated for the other driver groups.

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	$1.43	$0.88	68%	32%	$1.26	90	$113.22
Median	$2.66	$1.63	68%	32%	$2.34	90	$210.26
Upper-bound	$3.68	$2.26	68%	32%	$3.23	90	$291.13

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	1.01	58.99
Very High	70	2.98	67.02
Extreme	80	10.50	69.50

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 4-14 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. We then converted the number of hours worked by a driver with an average schedule of 52.1 hours per week to a fatigue percentage using the cumulative fatigue function, which equals 13 percent. For the very high intensity driver group, we take the difference between the fatigue percentage of the old average weekly work time for each category of drivers and the fatigue percentage for 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 work to determine the value of the change in crash risk for the reduction in crash risk that results from redistributing working hours to drivers working less intense schedules. For example, for the very high intensity drivers, the $8.95 average crash cost per hour of work is multiplied by the reduction in weekly work time for this group (2.98 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 $2.48 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	D	E = C x D x $8.95
Moderate	Lower-bound	7%			0.28	
	Median	13%			0.28	
	Upper-bound	18%			0.28	
High	Lower-bound	7%	8.95%	1.95%	1.01	$0.18
	Median	13%	16.6%	3.6%	1.01	$0.33
	Upper-bound	18%	23.00%	5.00%	1.01	$0.45
Very High	Lower-bound	7%	12.0%	5.0%	2.98	$1.34
	Median	13%	22.3%	9.3%	2.98	$2.48
	Upper-bound	18%	30.9%	12.9%	2.98	$3.43
Extreme	Lower-bound	7%	15.7%	8.7%	10.50	$8.13
	Median	13%	29.1%	16.1%	10.50	$15.11
	Upper-bound	18%	40.3%	22.3%	10.50	$20.92

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 67.02 hours (70 hours – 2.98 hours). We then used the function on the percent fatigue for each hour of weekly work 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 1.8 percent (22.3% – 20.5%). 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 work 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 $10.88 per week (1.8% x 67.02 weeks x $8.95) due to the reduction of the individual driver's own fatigue level. As shown in Exhibit D-14, 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	16.6%	16.12%	0.5%	59.0	$2.62
Very High	22.3%	20.5%	1.8%	67.02	$10.88
Extreme	29.1%	21.9%	7.1%	69.50	$44.46

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 benefit of $13.36 ($2.48 + $10.88) 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 $668 ($13.36 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-15, 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 $668 resulted in a total safety benefit for this category of drivers of $107 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 $390 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.)

Lastly, we calculated the total safety benefits for Option 2 by summing the total safety benefits resulting from the change in daily driving time ($210 million) and the total safety benefits resulting from the change in weekly work time ($390 million). As shown in Exhibit D-16, this resulted in total safety benefits of $600 million under the median assumption for the percent fatigue involvement. (This value is shown in Exhibit 6-5 of the RIA.)

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	$0.18	$1.41	$1.59	$79.43	304,000	$24,145,672
	Median	$0.33	$2.62	$2.95	$147.51	304,000	$44,841,962
	Upper-bound	$0.45	$3.63	$4.08	$204.24	304,000	$62,088,871
Very High	Lower-bound	$1.34	$5.86	$7.20	$359.76	160,000	$57,561,305
	Median	$2.48	$10.88	$13.36	$668.12	160,000	$106,899,567
	Upper-bound	$3.43	$15.07	$18.50	$925.09	160,000	$148,014,785
Extreme	Lower-bound	$8.13	$23.94	$32.07	$1,603.67	80,000	$128,293,936
	Median	$15.11	$44.46	$59.57	$2,978.25	80,000	$238,260,168
	Upper-bound	$20.92	$61.56	$82.47	$4,123.73	80,000	$329,898,694
			Lower Bound Total				**$210,000,914**
			Median Bound Total				**$390,001,697**
			Upper Bound Total				**$540,002,350**

Exhibit D-16. Total Safety Benefits of HOS Rule

	Value of Weekly Work Reduction (Millions)	Value of Eliminating the 11th Hour (Millions)	Total Safety Benefits (Millions)
	A	B	C = A + B
Lower-bound	$210	$110	$320
Median	$390	$210	$600
Upper-bound	$540	$290	$830

3. 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. As discussed in Chapter 5, FMCSA revised the methodology for calculating health benefits between the NPRM and Final Rule in response to comments. This revision recognizes that mortality benefits appear in the near term and values them using the full value of a statistical life (VSL) instead of the average loss of value of statistical life years (VSLYs).

The first step in estimating the change in expected mortality risk for Option 2 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 0.080 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 6.36 hours (6.28 hours + 0.080 hour) of sleep per night under 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	$A = (-0.00138 \times W^3 + 0.0235 \times W^2 - 0.183 \times W) - (-0.00138 \times B^3 + 0.0235 \times B^2 – 0.183 \times B)$	C	D = A + C
	Low	8.96	9.0	0.004	6.66	6.66
Moderate	Medium	8.96	9.0	0.004	7.02	7.02
	High	8.96	9.0	0.004	7.38	7.38
	Low	9.86	10.0	0.018	6.55	6.57
High	Medium	9.86	10.0	0.018	6.91	6.93
	High	9.86	10.0	0.018	7.27	7.29
	Low	11.2	11.7	0.080	6.28	6.36
Very High	Medium	11.2	11.7	0.080	6.64	6.72
	High	11.2	11.7	0.080	7.00	7.08
	Low	11.8	13.3	0.372	5.87	6.25
Extreme	Medium	11.8	13.3	0.372	6.23	6.61
	High	11.8	13.3	0.372	6.59	6.97

The next step in the calculation of health benefits was to translate the increased sleep due to the HOS rule provisions for Option 2 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 2.11 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 2.11 percent would be associated with an increased life expectancy of 2.11% x 11.56, or 0.2440 year. 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
	Low	6.66	6.66	0.04%	0.0047
Moderate	Medium	7.02	7.02	-0.02%	-0.0023
	High	7.38	7.38	-0.08%	-0.0094
	Low	6.55	6.57	0.28%	0.0323
High	Medium	6.91	6.93	-0.01%	-0.0016
	High	7.27	7.29	-0.31%	-0.0354
	Low	6.28	6.36	2.11%	0.2440
Very High	Medium	6.64	6.72	0.80%	0.0926
	High	7	7.08	-0.51%	-0.0588
	Low	5.87	6.25	14.20%	1.6416
Extreme	Medium	6.23	6.61	8.11%	0.9377
	High	6.59	6.97	2.02%	0.2339

The next step in calculating the health benefits of the HOS rule provisions for Option 2 is to monetize the estimated changes in mortality risk.

Our revised approach for the Final Rule values avoided deaths at the full VSL instead of the average loss of VSLYs for the population. To get the final benefit, we multiply the expected mortality improvement for our entire driver population of all intensity levels by the value of a 1 percent improvement in mortality calculated as shown. As one example, if the mortality improvement is 0.433 percent (the value calculated for Option 3 under the medium sleep assumption), the value per 1 percent improvement would be multiplied by 0.433 to yield the annual value of the health for one driver each age cohort. We then multiply the per-driver value by the number of drivers in the cohort. For example, the 50-60 year old cohort make up 26 percent of the total driver population of 1.6 million, so we multiply the per-driver value by 26 percent of 1.6 million, or 416,000 drivers. We then multiply the expected discounted per-driver benefit by the number of drivers (in this case $237.49 x 416,000). In the example, multiplying the per-driver value of $237.49 by 416,000 drivers in the cohort gives total present value benefits of $98.8 million for this age cohort. We repeated these calculations for each age cohort, and summed the figures for all cohorts to get a final estimated benefit for the entire population. We estimate the 1 percent mortality increase for the entire population at $805,050,342.

Next, using the change in mortality for each driver group and baseline sleep level, we estimate the total health benefit for Option 2. First we estimate a unit change in mortality for each driver group and baseline sleep level by dividing the change in mortality by 0.01. For example, for the very high driver group with the medium baseline level of sleep, we estimate a 0.80 (0.80% / 1%) of one percent increase in mortality. Next we multiply the 0.80 by the mortality value for 1 percent ($805 million) and the ratio of drivers in that cohort (10 percent). The resulting health benefit for the very high driver group with medium baseline levels of sleep is $64 million (0.80 x $805 million x 10%). Exhibit D-19 shows the calculations for all the driver groups under each assumption of baseline sleep. To estimate the entire health benefits, we sum across the different baseline levels of sleep to estimate a benefit of $806 million for the low baseline level of sleep, $378 million for the medium baseline level of sleep and -$50 million for the high baseline level of sleep.

Exhibit D-19. Calculation of Total Health Benefits by Driver and Sleep Type

Driver Group	Baseline Sleep	Change in Mortality from Increased Sleep	Unit Change in Mortality	Mortality Value	Ratio of Drivers	Total Health Benefits (Millions)
		A	B = A / 1%	C	D	E = B x C x D
Moderate	Low	0.04%	0.040	$805,050,342	66%	$22
	Medium	-0.02%	-0.020	$805,050,342	66%	-$11
	High	-0.08%	-0.080	$805,050,342	66%	-$43
High	Low	0.28%	0.280	$805,050,342	19%	$43
	Medium	-0.01%	-0.010	$805,050,342	19%	-$2
	High	-0.31%	-0.310	$805,050,342	19%	-$47
Very High	Low	2.11%	2.110	$805,050,342	10%	$170
	Medium	0.80%	0.800	$805,050,342	10%	$64
	High	-0.51%	-0.510	$805,050,342	10%	-$41
Extreme	Low	14.20%	14.200	$805,050,342	5%	$572
	Medium	8.11%	8.110	$805,050,342	5%	$327
	High	2.02%	2.020	$805,050,342	5%	$81
		Low Baseline Sleep Total				$806
		Medium Baseline Sleep Total				$378
		High Baseline Sleep Total				-$50

Appendix E – Estimate of Time Lost from the 2-night Provision for Restarts

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Appendix E – Estimate of the Time Lost from the 2-night Provision for Restarts

1. Introduction

This appendix contrasts two estimates of the weighted-average lost time per restart of the requirement that a restart break include 2 nights. One of these estimates, which corresponds to the requirement as specified in the Final Rule, requires that a driver be off-duty for two consecutive periods from 1:00 a.m. to 5:00 a.m. The other estimate was used for the NPRM, which defined the "night" for the purpose of the 2-night restart provision as midnight (12:00 a.m.) to 6:00 a.m.

Arriving at the estimate is a complex process. For a given restart, the critical variables are:

- The length of the restart break (i.e., the off-duty period of at least 34 consecutive hours that allows the driver to restart the cumulative tally of on-duty hours);
- Whether it covers 2 or 3 calendar days; and
- Times of day at which driver begins and ends the restart break.

Note that the last of these is a different variable from the length of the restart break. The effect of the 2-night provision on restart breaks of a given length will be different according to the times of day at the beginning and end of the restart break.

2. Length of Restart Break

The first consideration is the length of the restart break. If a break is 72 hours or longer, the driver does not need the restart provision to comply with the limit of 70 hours in eight days. Restart breaks are, therefore, limited to breaks of 34 to 71 hours.[1] Within that universe, many restart breaks are already compliant with the 2-night provision; drivers home for weekends with their families will usually spend two full nights at home before they go back to work. As a general principle, the longer a restart break is, the fewer cases there will be when it does not meet the 2-night restart provision. Any break of at least 52 hours is in compliance with the 1:00 a.m. to 5:00 a.m. provision.[2] From the 2007 FMCSA Field Survey [FMCSA (2007)], we know that 40.3 percent of breaks from 34 to 71 hours are 52 hours or longer.

2.1 2 Calendar Days or 3 Calendar Days

It is the case that many breaks of fewer than 52 hours will happen to be compliant with the 2-night restart provision. It is possible, in fact, for the minimal restart break of 34 hours to include two 1:00 a.m.-to-5:00 a.m. periods. This is true if the break spans 3 calendar days. If, for example, a driver stops at 11:00 p.m. on Monday and resumes work at 9:00 a.m. on Wednesday, he will have a 34-hour break with two nights, as shown in Exhibit E-1.

[1] Strictly speaking, breaks of 34 to 71.75 hours. Our data report restart length by the quarter-hour.
[2] Even in the worst case of a restart break beginning at a minute after 1:00 a.m., so that the first night is an incomplete period from 1:00 a.m. to 5:00 a.m., a break that covers the next 52 hours will still encompass the next two periods from 1:00 a.m. to 5:00 a.m.

Exhibit E-1. Compliant with the 2-night Provision

MON Hours	TUE Hours	WED Hours	Total Hours
1	24	9	34

If the break covers only 2 calendar days, it can be compliant with the 1:00 a.m. to 5:00 a.m. provision, if, and only if, the driver stops work between midnight and 1:00 a.m. on Tuesday. In Exhibit E-2, the driver stops at 1:00 a.m. on Tuesday and is compliant. If he stops after 1:00 a.m. on Tuesday, he cannot be in compliance without going over to a third day.

Exhibit E-2. 2-day Case Compliant with the 2-night Provision

MON Hours	TUE Hours	WED Hours	Total Hours
0	23	11	34

Further, a break that does include 3 calendar days (all of one day and parts of two others) is not necessarily compliant. It is non-compliant if the driver starts working again before 5:00 a.m. on Wednesday as in Exhibit E-3.

Exhibit E-3. Not Compliant with the 2-night Provision

MON Hours	TUE Hours	WED Hours	Total Hours
10	24	4	38

If a break comprises all of 3 calendar days, the 2-night restart provision is met, but it is not relevant. That is a 72-hour break, and the driver can return to work without benefit of the restart provision.

From these simple examples, we see that there are two distinct cases to consider:

- The 2-day case—driver is now compliant with a break that comprises parts of 2 calendar days; and
- The 3-day case—driver is now compliant with a break that includes all of 1 calendar day and parts of 2 other calendar days.

As already noted, all 2-day restarts would be non-compliant, except for the case where the driver stops between 12:00 a.m. (midnight) and 1:00 a.m. on Tuesday. Any restart of 52 or more hours would be compliant. Any 3-day restart where the driver returns to work after 5:00 a.m. on Wednesday would be compliant.

It is clear that the 2-day restart is used by a driver who is pushing hard—a driver who wants to be working again almost as soon as the rule will allow. The driver using the 3-day restart may be home for a weekend or out on the road but preferring to get more rest (or not having an immediate opportunity for a load).

We do not have good data on the total number of restarts taken, but we do have useful data on the length of restart breaks. Almost all of the hard-pushing drivers will be over-the-road, for-hire, and truckload drivers. Restarts do not matter for local drivers, who usually have weekends off and will not often work more than 50 hours in a week. Almost all over-the-road, LTL drivers have weekends at home, giving them two nights off. Drivers in private carriage tend to run on regular schedules that give them weekends at home.

The 2007 FMCSA Field Survey [FMCSA (2007)] has usable data on length of 1,689 restart breaks for over-the-road, for-hire, and truckload drivers. There are 1,721 entries, but we found it necessary to discard some of them. There is a question about the number of drivers reporting restarts of exactly 34 hours. The relevant entries from the FMCSA 2007 Field Survey are in Exhibit E-4.

Exhibit E-4. Number of Breaks by Length from 2007 FMCSA Field Survey

Length (Hours)	Entries
34.00	132
34.25	19
34.50	24
34.75	10
35.00	27

Compared to the subsequent entries, 132 for 34.00 hours seems excessive; some of these could be fake or erroneous entries. On the other hand, it is plausible that a disproportionate number of drivers, drivers who are pushing hard, might keep their restart breaks to the absolute minimum. Accordingly, we make a downward adjustment to 100 restart breaks in the interval 34.00-34.25 hours (which leaves 1,689 entries). This adjustment matters because it affects the average length of a 2-day restart break.

The data show restart breaks falling into two distinct sets: short and long breaks, roughly corresponding to the 2-day and 3-day cases. Forty-three percent of restart breaks are in the short set, concentrated in the range of 34 to 44 hours. There are two peaks in this range: 153 are below 35 hours and 70 are at 39 hours. Above 44 hours, the number of restart breaks for each hour of length drops considerably. There is a single peak—65 restart breaks that are 60 hours in length.

2.2 Times at Which Drivers Stop Work and Start Work

The average length of a short or 2-day restart break is 38 hours; the average length of a long or 3-day restart break is 57 hours.[3] Given the length of an average 2-day restart break, we can define the set of times of day for ending work to begin a restart break that are consistent with now-compliant 2-day restart breaks. Once this set of times is known, we can estimate the cost increment of meeting the 2-night restart provision, given a now-compliant 2-day restart break. The cost increment of meeting the 2-night restart provision, given a now-compliant 3-day restart break, can be estimated with the range of start-work times.

[3] Calculated from 2007 FMCSA Field Survey data.

It is first necessary to explain the way in which the data have been analyzed. In the 2005 FMCSA Field Survey results [FMCSA (2005)], end times and start times are recorded in 15-minute increments—e.g., 1:00, 1:15, 1:30, and 1:45. For end times, we have treated an even hour, e.g., 1:00, as the mid-point of a range over the previous and following half hours. The number of end times shown for 1:00 a.m. is the sum of the entries for 12:30 a.m. through 1:15 a.m. Put another way, it is the entries from 12:30 a.m. up to, but not including, the entries for 1:30 a.m. In effect, we take the mid-point of the range as an approximation of the average for the range.

Thus, when we say a driver stops at 2:00 a.m., he is stopping anywhere between 1:30 a.m and 2:30 a.m. This avoids a downward bias in the estimate of time lost when shifting backwards. If we said a driver stopping anywhere from 2:00 a.m. to 3:00 a.m. was stopping at 2:00 a.m., and counted the cost as 1 hour for going back before 1:00 a.m., we would undercount the time lost.

For start times at the end of the restart break, we count a start between 1:00 a.m. and 2:00 a.m. as a start at 1:00 a.m. This puts a slight upward bias in the accounting of time lost by going forward to a later start time.

3. Analysis of the 2-day Case

Given the 38-hour average for the 2-day case, a now-compliant driver must end work before 10:00 a.m. on the first day of the restart break (Tuesday in our example). If he ends work after 10:00 a.m., there are not 38 hours left in the 2-day period. Therefore, the end time must be in the range 1:00 a.m. to 10:00 a.m. In most cases, though not all, the least-cost way to meet the 2-night restart provision would be for the driver to stop before 1:00 a.m. on Tuesday. As the time cost of going back before 1:00 a.m. increases, however, the time cost of going forward and starting at 5:00 a.m. on Thursday decreases. We need to find the point at which the driver loses fewer hours by going forward to a later start time.

To calculate the cost of going forward in time, it is necessary to have a start-work time associated with each end-work time. We can do this using the finding that the average 2-day restart lasts for 38 hours. Calculation of the start time for each end time is best done using a 24-hour clock (which runs from 0000 to 2400 instead of 12 midnight to 12 midnight). We add 3800 hours to the end-work time and then subtract 2400 to bring the answer down to the start-work time the next day.

Start-work time = end-work time + 3800 - 2400.

Start-work time = end-work time + 1400.

For example, if end-work time on Tuesday is 0800, start-work time on Wednesday is 2200. (The restart break is 16 hours on Tuesday plus 22 hours on Wednesday.) Then, given work starting at 2200 on Wednesday, it would cost a driver 7 hours to move forward to a 0500 start on Thursday. Exhibit E-5 shows the analysis of hours lost by going back to end work before 1:00 a.m. on Tuesday or going forward to start work on Thursday after 5:00 a.m.

Exhibit E-5. Now-compliant 2-day Restart with Driver Stopping on Tuesday

End Time Tuesday	Hours Lost Going Back	Start Time Wednesday	Hours Lost Going Ahead to 0500 on Thursday	Least Hours Lost
0100	0.25	1500	14	0.25
0200	1	1600	13	1
0300	2	1700	12	2
0400	3	1800	11	3
0500	4	1900	10	4
0600	5	2000	9	5
0700	6	2100	8	6
0800	7	2200	7	7
0900	8	2300	6	6

For the 9:00 a.m. (0900) end time, the driver loses 6 hours by going forward to 5:00 a.m. on Thursday and 8 hours by going back before 1:00 a.m. on Tuesday. The hours lost by the least-cost choice for each end time are in the last column; it is these lost hours that are used to estimate the cost of the 2-night restart provision for the 2-day case.

There are two time intervals which are not whole hours—the ones associated with the first end-work time and the last end-work time. The first end-work time is where a driver stops between 1:00 a.m. and 1:30 a.m. In the analysis above, this is the 0100 end-work time. Time lost for the now-compliant driver stopping in this interval and forced to move back before 1:00 a.m. is counted as 0.25 hour. We assume the driver will move his stop time back no further than he has to.

The last end-work time in the analysis above is 0900. We treat this as 1.5 hours, the entries from 8:30 a.m. to 9:45 a.m.—the entries up to, but not including, the entries for 10:00 a.m. For drivers stopping between 8:30 and 9:30 a.m., the average time lost is 6 hours; these are the entries for 8:30, 8:45, 9:00, and 9:15. But, for drivers stopping between 9:30 a.m. and 10:00 a.m., the average time lost is 5.25 hours; these are the entries for 9:30 and 9:45. A driver stopping exactly at 9:30 a.m. on Tuesday starts at 11:30 p.m. on Wednesday and loses 5.5 hours by going forward to a 5:00 a.m. start on Thursday. If he ends work exactly at 10:00 a.m., he starts exactly at midnight and loses 5 hours by going forward to 5:00 a.m. on Thursday. Thus, the average loss for the drivers stopping in this half-hour interval is 5.25 hours. We adjust for this by multiplying the reported entries for 9:30 and 9:45 by the factor 5.25/6.

Exhibits E-6 and E-7, in which the dark spaces are time when the driver is in a restart break, provide graphic illustration of two of these cases.

Exhibit E-6. 38-hour Restart
(Driver now stops at 7:00 a.m. on Tuesday and backs up to before 1:00 a.m. on Tuesday—cost: 6 hours)

Non-compliant					Compliant				
Time	**Mon**	**Tue**	**Wed**	**Thurs**	**Time**	**Mon**	**Tue**	**Wed**	**Thurs**
12:00 a.m.					12:00 a.m.				
1:00 a.m.					1:00 a.m.				
2:00 a.m.					2:00 a.m.				
3:00 a.m.					3:00 a.m.				
4:00 a.m.					4:00 a.m.				
5:00 a.m.					5:00 a.m.				
6:00 a.m.					6:00 a.m.				
7:00 a.m.					7:00 a.m.				
8:00 a.m.					8:00 a.m.				
9:00 a.m.					9:00 a.m.				
10:00 a.m.					10:00 a.m.				
11:00 a.m.					11:00 a.m.				
12:00 p.m.					12:00 p.m.				
1:00 p.m.					1:00 p.m.				
2:00 p.m.					2:00 p.m.				
30:0 p.m.					30:0 p.m.				
4:00 p.m.					4:00 p.m.				
5:00 p.m.					5:00 p.m.				
6:00 p.m.					6:00 p.m.				
7:00 p.m.					7:00 p.m.				
8:00 p.m.					8:00 p.m.				
9:00 p.m.					9:00 p.m.				
10:00 p.m.					10:00 p.m.				
11:00 p.m.					11:00 p.m.				

In Exhibit E-6, the 12:00 a.m. cell in the compliant case is only partially filled in to make the point that a driver would not go all the way back to midnight on Monday in order to comply. As noted before, the rounding-off procedure does not include part of this hour in the estimate, except in the case of the driver stopping between 1:00 a.m. and 1:30 a.m.

Exhibit E-7 shows the case where a driver now starts at 11:00 p.m. on Wednesday and attains compliance by moving forward to start at 5:00 a.m. on Thursday.

Exhibit E-7. 38-hour Restart Break
(Driver now starts at 11:00 p.m. on Wednesday and goes forward to 5:00 a.m. on Thursday—cost: 6 hours)

Non-compliant					Compliant				
Time	**Mon**	**Tue**	**Wed**	**Thurs**	**Time**	**Mon**	**Tue**	**Wed**	**Thurs**
12:00 a.m.			■		12:00 a.m.			■	■
1:00 a.m.			■		1:00 a.m.			■	■
2:00 a.m.			■		2:00 a.m.			■	■
3:00 a.m.			■		3:00 a.m.			■	■
4:00 a.m.			■		4:00 a.m.			■	■
5:00 a.m.			■		5:00 a.m.			■	
6:00 a.m.			■		6:00 a.m.			■	
7:00 a.m.			■		7:00 a.m.			■	
8:00 a.m.			■		8:00 a.m.			■	
9:00 a.m.		■	■		9:00 a.m.		■	■	
10:00 a.m.		■	■		10:00 a.m.		■	■	
11:00 a.m.		■	■		11:00 a.m.		■	■	
12:00 p.m.		■	■		12:00 p.m.		■	■	
1:00 p.m.		■	■		1:00 p.m.		■	■	
2:00 p.m.		■	■		2:00 p.m.		■	■	
3:00 p.m.		■	■		3:00 p.m.		■	■	
4:00 p.m.		■	■		4:00 p.m.		■	■	
5:00 p.m.		■	■		5:00 p.m.		■	■	
6:00 p.m.		■	■		6:00 p.m.		■	■	
7:00 p.m.		■	■		7:00 p.m.		■	■	
8:00 p.m.		■	■		8:00 p.m.		■	■	
9:00 p.m.		■	■		9:00 p.m.		■	■	
10:00 p.m.		■	■		10:00 p.m.		■	■	
11:00 p.m.		■			11:00 p.m.		■	■	

4. Analysis of the 3-day Case

The 3-day case (shown in Exhibit E-8) presents a much simpler analytical issue. As already noted, non-compliance with the 2-night restart provision occurs only when the driver starts before 5:00 a.m. on the third day. Since there are 3 calendar days, some part of Monday must be included and all of Tuesday. Thus, he has a night off for the Monday/Tuesday night. The issue turns on when he starts work on Wednesday. If he starts work again before 5:00 a.m. on Wednesday he is out of compliance. Since compliance can be achieved only by moving the start time forward, the question of whether the driver goes forward or back in time does not exist. So the case can be analyzed with attention confined to the start time on Thursday morning.

Exhibit E-8. 3-day Restart Break
(Driver now starts work at 4:00 a.m. on Thursday and moves forward to start at 5:00 a.m.—cost: 1 hour)

Non-compliant				Compliant			
Time	**Tue**	**Wed**	**Thurs**	**Time**	**Tue**	**Wed**	**Thurs**
12:00 a.m.				12:00 a.m.			
1:00 a.m.				1:00 a.m.			
2:00 a.m.				2:00 a.m.			
3:00 a.m.				3:00 a.m.			
4:00 a.m.				4:00 a.m.			
5:00 a.m.				5:00 a.m.			
6:00 a.m.				6:00 a.m.			
7:00 a.m.				7:00 a.m.			
8:00 a.m.				8:00 a.m.			
9:00 a.m.				9:00 a.m.			
10:00 a.m.				10:00 a.m.			
11:00 a.m.				11:00 a.m.			
12:00 p.m.				12:00 p.m.			
1:00 p.m.				1:00 p.m.			
2:00 p.m.				2:00 p.m.			
3:00 p.m.				3:00 p.m.			
4:00 p.m.				4:00 p.m.			
5:00 p.m.				5:00 p.m.			
6:00 p.m.				6:00 p.m.			
7:00 p.m.				7:00 p.m.			
8:00 p.m.				8:00 p.m.			
9:00 p.m.				9:00 p.m.			
10:00 p.m.				10:00 p.m.			
11:00 p.m.				11:00 p.m.			

5. Developing the Estimates

5.1 The 2-day Case

To estimate time lost per restart in the 2-day case, we need the percentage of drivers that stop in the end times from 1:00 a.m. to 9:00 a.m. (For the 3-day case, we need the percentage of drivers that resume work in the start times from 12:00 a.m. to 5:00 a.m.) For this purpose, we rely on data from the FMCSA 2005 Field Survey [FMCSA (2005)] on times when drivers stop work and times when they start work.

As noted above, we adjust the number of drivers counted as stopping in the 9:30 a.m.-10:00 a.m. period. This is done by reducing the number of drivers stopping in the last half-hour by multiplying by a factor of 5.25/6 or 0.875. The data show 74 drivers stopping in the 9:00 a.m. hour and 48 stopping between 9:30 and 10:00.

48 x 0.875 = 42

We add 42 to 74 to obtain 116 drivers stopping in the 9:00 a.m. hour as defined. On the basis of the foregoing, we can now establish the percentages of drivers stopping in each hour in the 1:00 a.m. to 10:00 a.m. range and estimate the hours lost for the 2-day restart (presented in Exhibit E-9).

Exhibit E-9. 2-day Restart Break—Hours Lost

End Time	Hours Lost Per Driver	Percentage of Drivers	Adjusted Hours Lost
1:00 a.m.	0.25	1.0%	0.002
2:00 a.m.	1	2.0%	0.020
3:00 a.m.	2	1.5%	0.029
4:00 a.m.	3	1.8%	0.055
5:00 a.m.	4	1.8%	0.073
6:00 a.m.	5	2.9%	0.143
7:00 a.m.	6	3.1%	0.186
8:00 a.m.	7	2.4%	0.168
9:00 a.m.	6	3.6%	0.214
Totals		20.1%	0.891

For the average 2-day restart break, then, 0.891 hour is lost due to the 2-night restart provision.

5.2 THE 3-DAY CASE

For the 3-day case (presented in Exhibit E-10), we only look at start times on the third day (Thursday in our examples). Each hour is a full hour, 1:00 a.m. being 1:00-2:00, and so forth. A marked anomaly in the start-time data occurs with noon starts. The 2005 data show 404 entries for starts in the noon period, 125 for 11:00 a.m., and 119 for 1:00 p.m. Since the overall pattern is of starts peaking from 5:00 a.m. to 10:00 a.m., as one might expect, and declining thereafter, the 400-plus entries for noon cannot be accepted as valid. To fit the pattern in the rest of the data, we assign 124 entries for noon. There is also a minor issue for 12:00 a.m., the midnight to 1:00 a.m. period. The data show zero entries for this hour, but 54 entries for 11:00 p.m. and 54 entries for 1:00 a.m. The zero for 12:00 a.m. seems unlikely, so we assign a value of 24 for 12:00 a.m. On this basis, we can estimate the hours lost in the 3-day case.

Exhibit E-10. 3-day Restart Breaks—Hours Lost

Start Time	Hours Lost per Driver	Percentage of Drivers	Adjusted Hours Lost
12:00 a.m.	5	0.7%	0.037
1:00 a.m.	4	1.7%	0.066
2:00 a.m.	3	2.4%	0.071
3:00 a.m.	2	2.4%	0.048
4:00 a.m.	1	5.0%	0.050
Totals		**12.2%**	**0.272**

For the average 3-day restart break, 0.272 hour is lost due to the 2-night restart provision.

6. Combined Estimate of Cost for Average Restart under the Final Rule

To get the combined estimate, we weight the estimates for the two cases according to their share of all restarts. For this purpose, we can use data from the FMCSA 2007 Field Survey [FMCSA (2007)], which has data on lengths of restart breaks (shown in Exhibit E-11).

Exhibit E-11. Lengths of Restart Breaks from 2007 FMCSA Field Survey

Restart Breaks	Percentage
34 to 44 hours	43.0%
>44 to <72 hours	57.0%

0.43 x 0.891 + 0.57 x 0.272 = 0.538

The hours of work time lost due to the 2-night restart provision are 0.54 hour per average restart.

7. Estimate of Time Lost under the NPRM Restart Provision: 12:00 a.m.-6:00 a.m.

For the sake of comparison, it is useful to also make an estimate of time lost under the prior option: a “night” defined as 12:00 a.m.-6:00 a.m.

7.1 The 2-day Case 12:00 a.m.-6:00 a.m.

Under this option, no restart that includes only 2 calendar days can be compliant. A driver must either go back before midnight on Monday or forward to Thursday morning after 6:00 a.m. Exhibit E-12 presents the least hours lost for this option in the 2-day case. The first end time, 12:00 a.m., is the half-hour from 12:00 a.m. to 12:30 a.m., and the time cost to the driver of going back before midnight is 0.25 hour. The following table shows least hours lost for each end-work time.

Exhibit E-12. Now-compliant 2-day Restart Break with Driver Stopping on Tuesday (12:00 a.m.-6:00 a.m. Option)

End time Tuesday	Hours Lost Going Back to Monday	Start Time Wednesday	Hours Lost Going Ahead to 0600 on Thursday	Least Hours Lost
0000	0.25	1400	16	0.25
0100	1	1500	15	1
0200	2	1600	14	2
0300	3	1700	13	3
0400	4	1800	12	4
0500	5	1900	11	5
0600	6	2000	10	6
0700	7	2100	9	7
0800	8	2200	8	8
0900	9	2300	7	7

Before proceeding with the estimate of hours lost, we need to address an issue in the data on end-work times in the FMCSA 2005 Field Survey [FMCSA (2005)]. The data show a disproportionately large number of drivers stopping from midnight to 12:30 a.m. The data (presented in Exhibit E-13) show approximately 800 end times in this period followed by very few in the 12:30 a.m. to 1:00 a.m. period. This is out of about 4,000 entries for truckload, for-hire, and over-the-road carriers. For this reason, we did not use the entries for the midnight to 1:00 a.m. period, but, instead, interpolated from the entries on either side of this period, which show reasonable values. It is necessary to make separate estimates for 12:00 a.m. to 12:30 a.m. and for 12:30 a.m. to 1:00 a.m.

Exhibit E-13. Driver Stopping Times from 2005 FMCSA Field Survey Data

Period	Entries
11:00-11:30	56
11:30-12:00	27
12:00-12:30	**29**
12:30-1:00	**30**
1:00-1:30	32
1:30-2:00	23

Note: Estimated values in bold.

Accordingly, we use 29 as the number of drivers stopping in the first half-hour after midnight, designated as 12:00 a.m. in our system. We add the estimated 30 drivers stopping from 12:30 to 1:00 to the 32 from the data for 1:00 to 1:30 to obtain 62 drivers stopping from 12:30 to 1:30, designated as 1:00 a.m.

As with the 1:00 a.m.-5:00 a.m. requirement, the 9:00 a.m. end time is an interval of 1.5 hours: 8:30 to 10:00. The calculation for the adjustment of time lost in the last half-hour is different, however. For the requirement in the rule, the time lost is 6 hours for drivers in the 8:30-9:30 interval and 5.25 hours for the drivers in the 9:30-10:00 period. For the 12:00 a.m.-6:00 a.m. option, the time lost is 7 hours for drivers in the 8:30-9:30 interval and 6.25 hours for drivers in the 9:30-10:00 interval. So we adjust the number of drivers (48) in the 9:30 -10:00 interval by multiplying by a factor of 6.25/7—0.893—and add the result to the 74 entries in the 8:30-9:30 period.

0.893 x 48 = 42.9

74 + 43 = 117

With this adjustment, the time lost in the 2-day case is estimated as shown in Exhibit E-14.

Exhibit E-14. 2-day Restart Break—Hours Lost (12:00 a.m.-6:00 a.m. Option)

End Time	Hours Lost per Driver	Percentage of Drivers	Adjusted Hours Lost
12:00 a.m.	0.25	0.9%	0.002
1:00 a.m.	1	1.9%	0.019
2:00 a.m.	2	2.0%	0.041
3:00 a.m.	3	1.5%	0.044
4:00 a.m.	4	1.8%	0.074
5:00 a.m.	5	1.8%	0.091
6:00 a.m.	6	2.9%	0.171
7:00 a.m.	7	3.1%	0.217
8:00 a.m.	8	2.4%	0.192
9:00 a.m.	7	3.6%	0.252
Totals		21.9%	1.102

7.2 THE 3-DAY CASE 12:00 A.M.-6:00 A.M.

The only change from the provision in the Final Rule is that the range of start times is increased to 12:00 a.m.-5:00 a.m. (presented in Exhibit E-15). A driver starting after 6:00 a.m. is compliant.

Exhibit E-15. 3-day Restart Break—Hours Lost (12:00 a.m.-6:00 a.m. Option)

Start Time	Hours Lost per Driver	Percentage of Drivers	Adjusted Hours Lost
12:00 a.m.	6	0.7%	0.044
1:00 a.m.	5	1.7%	0.083
2:00 a.m.	4	2.4%	0.095
3:00 a.m.	3	2.4%	0.072
4:00 a.m.	2	5.0%	0.101
5:00 a.m.	1	6.2%	0.062
Totals		18.4%	0.456

7.3 Combined Estimate of Cost for Average Restart under the 12:00 a.m.-6:00 a.m. Option

The 2-day restart breaks are 43.0 percent of the total, and the 3-day restart breaks are 57.0 percent of the total.

0.43 x 1.102 + 0.57 x 0.456 = 0.734

Thus, the average time lost per restart is 0.73 hour under the 12:00 a.m.-6:00 a.m. option. This average is notably higher than the 0.54 hour per restart lost under the requirement in the final rule. The difference is largely due to the shorter ranges of end-work and start-times that are affected by the rule as compared to the prior option.

8. References

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