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 x W^3 + 0.0235 x W^2 - 0.183 x W) - (-0.00138 x B^3 + 0.0235 x B^2 – 0.183 x B)	C	D = A + C
Moderate	Low	8.96	9.0	0.004	6.66	6.66
	Medium	8.96	9.0	0.004	7.02	7.02
	High	8.96	9.0	0.004	7.38	7.38
High	Low	9.86	10.0	0.018	6.55	6.57
	Medium	9.86	10.0	0.018	6.91	6.93
	High	9.86	10.0	0.018	7.27	7.29
Very High	Low	11.2	11.7	0.080	6.28	6.36
	Medium	11.2	11.7	0.080	6.64	6.72
	High	11.2	11.7	0.080	7.00	7.08
Extreme	Low	11.8	13.3	0.372	5.87	6.25
	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	$A = (3.1377 \times B + 0.2274 \times B^2) - (3.1377 \times S + 0.2274 \times S^2)$	$C = A \times 0.1156$
Moderate	Low	6.66	6.66	0.04%	0.0047
	Medium	7.02	7.02	-0.02%	-0.0023
	High	7.38	7.38	-0.08%	-0.0094
High	Low	6.55	6.57	0.28%	0.0323
	Medium	6.91	6.93	-0.01%	-0.0016
	High	7.27	7.29	-0.31%	-0.0354
Very High	Low	6.28	6.36	2.11%	0.2440
	Medium	6.64	6.72	0.80%	0.0926
	High	7	7.08	-0.51%	-0.0588
Extreme	Low	5.87	6.25	14.20%	1.6416
	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