# REGULATORY IMPACT ANALYSIS AND SMALL BUSINESS IMPACT ANALYSIS FOR HOURS OF SERVICE OPTIONS

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## LIST OF ACRONYMS

| | |
|---|---|
| ATA | American Trucking Associations |
| BEA | Bureau of Economic Affairs |
| CMV | Commercial Motor Vehicle |
| DFACS | Driver Fatigue, Alertness, and Countermeasures Study |
| DOT | Department of Transportation |
| ES | Executive Summary |
| FARS | Fatality Analysis Reporting System |
| FMCSA | Federal Motor Carrier Safety Administration |
| GDP | Gross Domestic Product |
| GES | General Estimates System |
| HOS | Hours of Service |
| IIHS | Insurance Institute for Highway Safety |
| LCM | Logistics Cost Model |
| LH | Long-Haul |
| LTL | Less-than-Truckload |
| MCMIS | Motor Carrier Management Information System |
| NAICS | North American Industrial Classification System |
| NHS Act | National Highway System Designation Act of 1995 |
| NHTSA | National Highway Traffic Safety Administration |
| NPRM | Notice of Proposed Rulemaking |
| OOIDA | Owner-Operators Independent Drivers Association |
| OTR | Over the Road |
| PVT | Psychological Vigilance Task |
| RIA | Regulatory Impact Analysis |
| SBA | Small Business Administration |
| SH | Short-Haul |
| SPM | Sleep Performance Model |
| TL | Truckload |
| TOT | Time on Task |
| UMTIP | University of Michigan Trucking Industry Program |
| UPS | United Parcel Service |
| VIUS | Vehicle Inventory and Use Survey |
| VMT | Vehicle Miles Traveled |
| VPI | Virginia Polytechnic Institute |
| WRAIR | Walter Reed Army Institute of Research |
| WRAIR-SPM | Walter Reed Army Institute of Research – Sleep Performance Model |

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# EXECUTIVE SUMMARY

This Regulatory Impact Analysis (RIA) provides an assessment of the costs and benefits of potential changes in Department of Transportation Federal Motor Carrier Safety Administration (FMCSA) Hours of Service (HOS) regulations. The HOS regulations address the number of hours that a commercial motor vehicle driver (CMV) may drive, and the number of hours a CMV driver may be on duty, after which driving is prohibited until a minimum off-duty rest period is taken.

A new HOS rule was promulgated on April 28, 2003 (68 FR 22456) and implemented on January 4, 2004 with the goal of reducing the incidence of fatigue-related crashes. That rule increased the required rest between tours of duty from 8 to 10 hours (which could be split into two sleeper-berth periods under some conditions), allowed drivers to restart their calculation of duty hours in a multi-day period if they took a continuous off-duty break of at least 34 hours, and lengthened the driving period between offduty rest periods from 10 to 11 hours.

After the new rule had been in effect for several months, it was vacated by the United States Court of Appeals for the District of Columbia Circuit (D.C. Circuit). [*Public Citizen et al. v. Federal Motor Carrier Safety Administration*, 374 F.3d 1209, at 1216.] The D.C. Circuit found, on July 16, 2004, that FMCSA had not considered effects on drivers' health. It also expressed concerns about the 11th driving hour, the restart of the multi-day duty-hour calculation, the use of sleeper berths to split the rest period, and the lack of consideration of electronic on-board recorders. In response to the court's action, Congress extended the 2003 rule for a year, in order to give FMCSA a chance to revisit the issues cited by the court. As such, the FMCSA has reexamined its HOS regulations in light of the D.C. Circuit *Public Citizen* decision.

## ES.1 OPTIONS

This analysis considers and assesses the potential consequences of four potential regulatory options.

Option 1 is the continued implementation of the current 2003 HOS regulations, with no additional rule changes and no changes in the method of implementation. The FMCSA would continue to enforce the current HOS regulations. The existing exemptions to the current HOS regulations under the NHS Act would remain in effect.

Option 2 changes the regulations in a way that is intended to improve safety while maintaining their most important advantages: it constrains the use of sleeper berths to ensure that each sleeper berth period is at least 8 hours, and is supplemented by a 2-hour break that may be outside the sleeper berth.

Options 3 and 4 are more stringent than Options 1 or 2. Operators are limited to 10 (rather than 11) hours of driving in a tour of duty, the use of split sleeper berth periods is eliminated, and the length of the restart break is expanded to 58 hours in Option 3 and 44 hours in Option 4.

In addition, for Options 2, 3, and 4, short-haul operators of vehicles not requiring a commercial driver's license (CDL), or typically those of less than 26,000 lbs gross vehicle weight rating (GVWR), and remaining within a 150 mile radius of their base, may keep timecards in lieu of logbooks and may be on-duty up to 16 consecutive hours two days during a seven-day work week.

## ES.2 OVERVIEW OF THE ANALYSIS

The analysis of costs recognizes that the different provisions of the options will affect carrier operations in complex and interacting ways. It also recognizes that these effects will depend strongly on the carriers' baseline operating patterns, which vary widely across this diverse industry. To produce a realistic measurement of the impacts of each option, we divided the industry into broad segments, collected information on operations within these segments, and then created a model of carrier operations as they are affected by HOS rules. Given the very wide array of operational patterns, it was necessary to limit the analysis to the most important cases.

The model was first loaded with data representative of shipping patterns and carrier cost structures, and tested to ensure that it could realistically simulate typical lengths of haul, empty mile ratios, and productivity. It was then set up to cover most important cases, under constraints representing each option, and used to simulate carrier operations under different conditions and HOS rules. We then analyzed the data representing the simulated operations, using changes in miles driven as a measure of productivity impacts. Output measures from individual runs were weighted to give a realistic representation of the affected industry, including the drivers' use of the most important provisions of the options. The weighted changes in productivity from this procedure were then used to estimate the cost increases imposed on the industry by each option, using an analysis of the changes in wages and other costs likely to result from changes in productivity. These productivity-related costs were combined with transition costs associated with shifting to new rules to produce estimates of total social costs.

Safety impacts were measured by feeding the on duty and driving schedules from the carrier simulation model into an operator fatigue model to project driver effectiveness levels, and then using the fatigue model results to estimate the resulting changes in crash risks under each HOS option and for the different operations cases. Changes in fatigue-related crash risks, calibrated to match realistic levels, were then multiplied by the value of all affected crashes to yield estimates of total benefits.

Finally, impacts on affected carriers were assessed using a pro-forma model of carrier operations for different carrier sizes, allowing for the effects of changes in driver wage rates and prices of trucking services.

## ES.3 RESULTS

The results of the analysis are presented in two parts: for long-haul (LH) operations, and then for short-haul (SH) operations. The results of the simulation modeling of LH operations are shown in Exhibit ES-1, which presents impacts for drivers in operations of different average lengths of haul (short regional or SR, long regional or LR, and long-haul or LH), different degrees of schedule regularity (random or regular), different work weeks (those working five as opposed to six days per week), different sleeper berth usage, and for solo drivers and teams. The impacts on driver productivity of Options 2, 3, and 4, relative to Option 1, varied widely for runs simulating these different types of operations. The impacts tended to be greater for drivers assumed to take advantage of split sleeper berths, for drivers with short to moderate average lengths of haul. Overall, though, eliminating the split sleeper berth break appeared to be of minor importance for the productivity of solo drivers. This observation is likely due to the fact that, while the opportunity to initiate a split break provides flexibility, the rules for using this feature imparts rigidity to a driver's schedule for subsequent tours of duty. The fact that the change in the rules for splitting breaks is the only difference between Options 1 and 2, combined with the lack of a large productivity impact from restrictions on splitting and limited use of splitting, means that the productivity impacts of Option 2 are slight.

**Exhibit ES-1**
**Estimated Changes in Long-Haul Productivity by Option and Case**

| | | | **Option 2 Compared to Option 1** | **Option 3 Compared to Option 1** | **Option 4 Compared to Option 1** |
|---|---|---|---|---|---|
| **Run characteristics** | | | **Relative Reduction in driving hours** | | |
| For-hire, random | Using split sleeper berths | Short Regional (SR) | 1.1% | 24.9% | 10.3% |
| | | Long Regional (LR) | 5.9% | 26.2% | 19.4% |
| | | Long Haul (LH)[**] | -3.1% | 17.9% | 9.6% |
| | | | | | |
| | No split sleeper berths | SR | 0% | 24.1% | 9.3% |
| | | LR | 0% | 21.4% | 14.2% |
| | | LH | 0% | 20.4% | 12.5% |
| Regular Routes (Private TL, LTL, regular for-hire) | Full weekend off | Weekly route | 0% | 16.1% | 5% |
| | | Daily route[**] | 0% | -2.0% | -1% |
| | Six-day work week | Weekly route | 0% | 29.2% | 19% |
| | | Daily route | 0% | 8.9% | 10% |
| Team drivers[*] | Using split sleeper berths | | 0% | 5.0% | 5.0% |
| | No split sleeper berths | | 0% | 5.0% | 5.0% |

[*] These impact estimates were based on simplified scenarios rather than model runs.
[**] These negative impacts are the results of random factors in the simulation, and would not persist if they were repeated a large number of times.

Because they limit driving hours and require longer restart periods, the relative productivity loss caused by Options 3 and 4 are substantially greater than that for Option 2 in almost all cases. Also, in almost all cases, the impact of Option 3 is greater than that of Option 4, due to the longer restart required under Option 3. The impacts of changes in the restart period are particularly large for the random drivers, whose lack of a regularly scheduled off-duty period means that a short restart can be very advantageous. For Options 3 and 4, the team drivers were expected to lose 5 percent of their productivity as a result of the loss of the 11th hour of driving: even if the members of a driving team want to average only 10 hours of driving per day, random factors will tend to push them slightly over 10 hours on some days, and slightly under on other days. If they are limited to no more than 10 hours, however, they will tend to average somewhat less than 10 hours as a result of the times when they cannot use all of the 10 hours that are permitted. No impacts are seen for team drivers under Option 2 because of the ability of team drivers to achieve the same productivity whether or not they split their break periods.

The productivity impacts shown in ES-1 were weighted to produce an industry-wide estimate of average impacts using data on the prevalence of different operating patterns and different degrees of use of several important features of the existing HOS rules. The weighted productivity impacts, which are shown in Exhibit ES-2, came to -0.042% for Option 2, -7.12% for Option 3, and -4.61% for Option 4, all relative to Option 1.

The impact of these changes in productivity were estimated using analyses of the changes in costs (for labor and equipment) as a function of changes in hours worked, due to the need to hire more drivers as the productivity of each existing driver is reduced. These analyses showed that each one percent change in driver productivity is associated with just under $300 million in costs. Multiplying the weighted average productivity impacts by the costs per percent decrease in productivity yields $13 million, $2.12 billion, and $1.37 billion per year for the incremental effects of Options 2, 3, and 4, respectively. In addition, retraining of drivers and other personnel is expected to add an annualized $21 million to the costs of Options 2, 3, and 4. It should be noted here that while retraining costs may in fact vary somewhat by Alternative Option, the RIA for today's rule assumed these costs are constant. For example, under Option 2, while it might be the case that certain carriers would only retrain their long-haul drivers who currently use the sleeper berth provision, it may also be the case that some carriers would want to train their entire driver workforce (depending on how many drivers currently use the sleeper berth provision versus those who may use it in the future). As such, retraining costs for Option 2 could be considered conservative, in that they may overrepresent the true retraining costs associated with this option.

The total cost impacts of the options on the LH sector, relative to Option 1, are shown in Exhibit ES-2. ES-2 also shows anticipated changes in LH drivers (not counting small changes related to mode shift).

**Exhibit ES-2**
**Incremental Annual Costs of the Options for LH Operations**
**Relative to Option 1**

| | Option 2 | Option 3 | Option 4 |
|---|---|---|---|
| **Change in LH Productivity** | 0.042% | 7.12% | 4.61% |
| **Change in Annual Costs due to Productivity Impact (millions of 2004$)** | $13 | $2,121 | $1,374 |
| **Incremental Annualized Retraining Cost (millions of 2004$)** | $21 | $21 | $21 |
| **Total Annual Incremental Cost** | $34 | $2,142 | $1,395 |
| **Increase in Numbers of Drivers** | 600 | 107,000 | 69,000 |

Source: ICF analysis.

### Cost Impacts of the Options on SH Operations

The analysis concentrates on the LH segment of the motor carrier industry because the major HOS provisions differentiating the four alternative options considered here are expected to have little or no effect on local and SH operations. Two provisions of Options 2, 3, and 4, however, affect only local/SH drivers: the exemption from keeping log books, and a second 16-hour day in each week. These two provisions apply only for drivers of vehicles between 10,000 and 26,000 lbs. GVWR that stay within a 150 air-mile radius of their base of operations, and return to that base at the end of each tour of duty.

We have estimated the cost impacts of these provisions by dividing local/SH vehicles into a limited set of cases, determining the time savings of the log-book exemption for each vehicle in each case, and valuing those savings per vehicle. We then estimated the number of vehicles in each case, multiplied by the savings per vehicle, and summed across the cases.

We estimated the savings from the second 16-hour day per week using a variant of the analysis of the savings from the first 16-hour day per week, which was conducted for the 2003 RIA. Those estimated savings were translated into an annual per-vehicle value, and then scaled appropriately for our estimate of the number of affected vehicles. These cost estimates are shown in Exhibit ES-3.

**Exhibit ES-3**
**Summary of Local/SH Analysis**
**(Annual Savings in Millions of 2004$, rounded to the nearest $10 million)**

| | **Case 1** | **Case 2** | **Case 3** | **Total Annual Savings (millions)** |
|---|---|---|---|---|
| Description | Now operating within 100-mile range and not keeping logs. Duty tours ≤ 12 hours. | Now operating within 100-mile range and keeping logs. Duty tours up to 14 hours. | Now operating in 100-150 mile range. Must keep logs and observe 14-hour limit. | |
| Log-book effects | No effect; already exempt from log requirement. Benefit: $0 | Relieved from log requirement. Benefit: $100. | Relieved from log requirement. Case-3 benefit: $40 | $140 |
| 14-hour tour with log-book exemption | May use 14-hour tour now, if they keep log. Tour>12 hours is of little value to this group. Benefit: minimal | Already choosing log-book and 14-hour tour. Benefit: zero | Already have 14-hour tour. Benefit: zero | $ 0 |
| Second 16-hour day | Would not use the 16-hour day because they already choose not to use the 14-hour tour. Savings: $0 | Analysis is an extension of analysis of second 16-hour day that was done for the 2003 RIA. This approach did not distinguish between Cases 2 and 3. Productivity Benefits: $140 | | $140 |
| Total | | | | $280 |

Source: ICF analysis. See Appendix (IV).

## Crash Risk Results by Operational Case

The results of the crash risk modeling are presented in the table below, after scaling the results to yield an average fatigue-related value of 7 percent in Option 1. Overall, the impacts are relatively small, as might be expected for options that are making marginal changes in an existing rule. Weighting the crash risk results in the same manner as the productivity results, we found the overall changes in crash risks to be small. Option 2 resulted in a risk reduction of about 0.1 percent, while Options 3 and 4 each provided a risk reduction of about 0.6 percent.

**Exhibit ES-4**
**Incremental Crash Risk Estimates**

| | | | **Option 2 Compared to Option 1** | **Option 3 Compared to Option 1** | **Option 4 Compared to Option 1** |
|---|---|---|---|---|---|
| **Run characteristics** | | | **Relative Change in Crash Risk** | | |
| For-hire, random | Using split sleeper berths | Short Regional (SR) | -7.4% | -6.3% | -2.4% |
| | | Long Regional (LR) | 1.4% | -5.6% | -7.5% |
| | | Long Haul (LH)** | 2.0% | -7.2% | -7.6% |
| | | | | | |
| | No split sleeper berths | SR | 0% | 1.1% | 5.0% |
| | | LR | 0% | -6.9% | -8.9% |
| | | LH | 0% | -9.3% | -9.6% |
| Regular routes (Private TL, LTL, regular for-hire) | Full weekend off | Weekly | 0% | 0.2% | -0.4% |
| | | Daily | 0% | -0.7% | -0.3% |
| | Six-day work week | Weekly | 0% | -0.7% | -1.2% |
| | | Daily | 0% | -0.9% | -0.5% |
| Team drivers* | Using split sleeper berths** | | -5.7% | -6.4% | -6.4% |
| | No split sleeper berths | | 0% | -0.7% | -0.7% |
| Weighted Average Impacts (raw) | | | -0.3% | -1.4% | -1.4% |
| Weighted Average Impacts (scaled) | | | -0.1% | -0.6% | -0.6% |

*These impact estimates were based on simplified scenarios rather than model runs.
**These scenarios assumed time-on-task effects for split sleeper berth cases are of the same magnitude as in equivalent non-split cases. Reductions in crashes would be smaller if split rest periods eliminate time-on-task effects.

## Value of the Crash Risk Changes

These percentage changes in risk were valued by multiplying them by an estimate of the total annual damage associated with heavy-duty long-haul truck crashes. For consistency with the earlier analysis, we have used the value from the previous analysis of $32.2 billion in year 2000 dollars, or about $34.9 billion in year 2004 dollars. This was done so that the RIAs for the 2003 rule and today's rule would be as closely linked as possible, such that the comprehensive economic effects of the two analyses could be examined together. This total was multiplied by the percentage of total damages that were caused by the long-haul segment, yielding just over $20 billion. The reduction in risk attributable to Option 2, given this total value, is 0.1% * $20 billion or about $20 million per year. The risk reduction attributable to Options 3 and 4 is higher, at about $120 million per year. Changes under Options 3 and 4 are much smaller than the cost changes attributable to the options. The crash risk impacts of the local/SH changes are expected to be negligible.

**Net Costs by Option**

Exhibit ES-5 summarizes the annualized costs, benefits, and net costs of each of the options relative to Option 1. Both LH and local/SH effects are shown. The values have been rounded to the nearest $10 million, in line with the values presented for the local/SH impacts.

**Exhibit ES-5**
**Net Incremental Annual Costs of the Options Relative to Option 1**
**(millions of 2004$, rounded to nearest $10 million)**

| | | Option 2 | Option 3 | Option 4 |
|---|---|---|---|---|
| **Total Annual Incremental Cost** | **LH** | $30 | $2,140 | $1,390 |
| | **SH** | -$280 | -$280 | -$280 |
| **Total Crash Reduction Benefits** | **LH** | $20 | $120 | $120 |
| | **SH** | ~0 | ~0 | ~0 |
| **Net Annual Costs** | | -$270 | $1,740 | $990 |

Source: ICF analysis.

**Sensitivity Analysis for a 10-hour Driving Limit**

In addition to examining options 2, 3, and 4 relative to Option 1, a variant of Option 2 was considered. This variant combined the other features of Option 2 with the 10-hour driving limit included in Options 3 and 4. This option was found to be considerably less cost-effective than the basic version of Option 2, as shown in the first row of Exhibit ES-6. Whereas Option 2 has net benefits of $270 million per year, the 10-hour variant has net benefits of *negative* $256 million per year (i.e., it has net costs). The conclusion that imposing a 10-hour driving limit was not cost-effective was tested by reexamining costs and benefits under a series of sensitivity assumptions, which are shown in the other rows of Exhibit ES-6. Doubling the assumed use of the $11^{th}$ hour increased the *net costs* of the 10-hour variant from $256 million to $782 million, making Option 2 with 10 hours driving even less cost effective relative to Option 2. More than tripling the value for each statistical life saved (from $3 million to $10 million) improved the relative cost effectiveness of Option 2 with 10 hours driving, but it was still neither cost beneficial on its own (with net costs of $170 million) nor cost effective relative to Option 2. Also, raising the relative risk of a fatigue-related crash in the $11^{th}$ hour of driving by 1.4 times the value used in time-on-task (TOT) multiplier in the RIA did not make Option 2 with 10 hours driving cost effective relative to Option 2 ($232 in net costs versus $270 in net benefits respectively), nor did substantially raising the baseline level of fatigue in truck-related crashes (i.e., $189 million in net costs for Option 2 with 10 hours driving relative to $287 million in net benefits for Option 2). Each change improved the showing of the 10-hour variant, but still left it with net costs rather than net benefits. Only in a very unlikely scenario that combines all three of the assumptions favorable to the 10-hour limit does the 10-hour variant show any net benefits. Even in this scenario, though, its net benefits are far below that of Option 2 without the 10-hour restriction, indicating that it is implausible that eliminating the 11th hour would be cost-effective.

**Exhibit ES-6**
**Sensitivity Analyses of Net Benefits, 10-hour Driving Limit**
**(millions of 2004$)**

| | Net Benefits of Option 2 | Net Benefits of Option 2 w/10 hrs |
|---|---|---|
| Basic Assumptions | 270 | -256 |
| Twice as Much Use of 11th Hour | 270 | -782 |
| Higher Value of Statistical Life (VSL) | 291 | -170 |
| Higher TOT Impact | 270 | -232 |
| Higher Baseline Fatigue | 287 | -189 |
| Higher VSL, TOT Impact, and Baseline Fatigue | 326 | 60 |

## ES.4 Impacts on Carriers

For representative carriers in each of several carrier size categories, the financial impact of each HOS rule option was estimated in terms of the change in net income (in 2004$) to the carrier,[1] as well as a change in their profits as a fraction of operating revenues. The approach used to estimate these impacts involved the development of a pro forma financial model of firms of different sizes confronted by changes in productivity, wages, and prices. Financial impacts of Options 2, 3, and 4 relative to Option 1 were estimated under two assumptions about prices of trucking services: unchanged prices (representing the short run), and prices after industry-wide cost changes have been passed through to consumers.

Relative to Option 1, all of the other options result in adverse financial impacts (reduced profits) on most carriers. The severity of the impacts is directly related to the magnitude of the drop in labor productivities considered for the three options. Option 2 revealed the least severe adverse impacts. Under Option 2, in the period before prices adjust, profitability as a share of revenue is projected to decrease by a tenth of one percent or less across all size classes, relative to Option 1. These impacts should be reduced slightly as prices adjust. Option 3 has the most severe impacts on carriers, and could eliminate net income in the short term for some industry size categories. Option 4 shows impacts that are in-between the two extremes.

[1] Representative carriers for the four largest size categories were selected on the basis of having the median value in the category for profitability (as measured by the ratio of net income to total revenue).

The results in terms of profit impacts relative to revenues under Option 2 seem to suggest very small impacts for firms across the wide range of size categories examined, including both large and small entities. The threshold for impacts considered to be of moderate size is generally taken to be one percent of revenues, and the average impacts of Option 2 fall well below that magnitude. It should also be noted that even though Option 2 would result in slightly lower profitability than Option 1, carriers would generally earn higher net revenues than they were under the pre-2003 rule, only a short time ago. Though variability in impacts within each size category means that the possibility of larger impacts for some small entities cannot be ruled out, the small magnitude of the total impact means that no more than a small percentage of entities could face significant impacts under Option 2.

# 1. BACKGROUND

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

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

## The Revised Rule

Revisions to the HOS regulations were proposed in a Notice of Proposed Rulemaking (NPRM) published in the May 2, 2000 Federal Register (65 FR 25540). Following reviews of the comments on the NPRM and additional study, the Federal Motor Carrier Safety Administration (FMCSA) developed a revised set of HOS regulations. The new rule was promulgated on April 28, 2003 (68 FR 22456) and took effect on January 4, 2004. A regulatory impact analysis (RIA) comparing the costs, benefits, and impacts of this rule relative to the previous rule and several alternatives was conducted in accordance with the requirements of Executive Order 12866. That RIA, which is available in the HOS rule docket, http://dmses.dot.gov/docimages/pdf88/240882_web.pdf, showed that full compliance with the new rule (the "2003 HOS rule") could both save lives and increase productivity compared to full compliance with the rule then in existence. Much of the safety advantage of the 2003 HOS rule was shown to come from the mandate for at least 10 hours off for each tour of duty, and from the contribution to keeping drivers on a regular 24-hour cycle. The contributions of the new regulations to productivity came from a provision allowing drivers to "restart" the accumulation of their 60 or 70 hours on-duty within 7 or 8 days once they took 34 hours off at one stretch.

## The Appeals Court Action

After the 2003 HOS rule had been in effect for several months, it was vacated by a federal appeals court. The D.C. circuit court found, on July 16 2004, that FMCSA had not considered effects on drivers' health, and had concerns about several areas of the rule:

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

- Lack of consideration of the electronic on-board recorders.

In response to the court's action, Congress extended the 2003 rule for a year, in order to give FMCSA a chance to revisit the issues cited by the court.

## 1.1 Purpose and Need for Proposed Action

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

- Operators can cumulatively drive up to 11 hours or be on duty up to 14 consecutive hours since the end of their last 10-consecutive-hour break.[2]

- Operators can cumulatively drive or be on-duty up to 60 hours over the last 7 consecutive 24-hour periods, or 70 hours over the last 8 24-hour periods.

- If a sleeper berth is used, the 10-hour break can be split into two periods of no less than 2 hours each, provided that the duty periods preceding and following each of these two periods sum to no more than 14 hours.

- Operators who obtain 34 consecutive hours of off-duty time can begin a new seven-day period, over which they can be drive or be on duty a cumulative total of 70 hours (i.e., the seven-day "clock" is restarted by a 34-hour off-duty period).

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

The purpose of the proposed action is to further improve CMV safety by revising the FMCSA HOS regulations to require motor carriers to provide CMV drivers with better opportunities to obtain sleep, in order to reduce the incidence of drowsy, tired, or fatigued drivers and the crashes in which they are involved.

## 1.2 Options

This analysis considers and assesses the potential consequences of four potential regulatory options. Option 1 is to readopt the 2003 rule. The others are referred to as Option 2, Option 3, and Option 4. The options and the rationale behind their provisions are described briefly in this section.

[2] To be more exact, drivers cannot drive after they have been on-duty 14 cumulative hours after their last 10-consecutive-hour break.

### 1.2.1 Option 1

Option 1 is to readopt the 2003 HOS rule, with no additional rulemaking and no changes in the method of implementation. The FMCSA would continue to enforce the 2003 HOS regulations without change. The existing exemptions to the current HOS regulations under the NHS Act would remain in effect.

The 2003 rule is divided into daily and multi-day provisions, which can be expressed as follows:

- Operators can drive up to 11 hours within a period of 14 consecutive hours from the start of the duty tour, followed by a break of 10 consecutive hours.
- Short-haul operators can be on-duty up to 16 consecutive hours one day during a seven-day work week so long as two such days do not occur consecutively.
- Operators can cumulatively drive or be on-duty up to 60 hours over the last seven days or 70 hours over the last eight days.
- If a sleeper berth is used, the 10-hour break can be split into two periods of no less than 2 hours each, provided that the duty periods preceding and following each of these two periods sum to no more than 14 hours.
- Operators who obtain 34 consecutive hours of off-duty time can begin a new seven-or eight-day period, over which they can drive or be on duty a cumulative total of 60 or70 hours respectively (i.e., the seven- or eight-day "clock" is restarted by a 34-hour off-duty period).

### 1.2.2 Option 2

This option changes the 2003 rule in a way that is intended to improve safety while readopting their most important advantages.

- The use of split sleeper berth periods is limited such that one of the two periods must be at least 8 hours long.
- Short-haul operators of vehicles less than 26,000 lbs GVW, remaining within a 150 mile radius of their base, may keep timecards in lieu of logbooks and may be on-duty up to 16 consecutive hours two days during a seven-day work week.
- As under Option 1, operators who obtain 34 consecutive hours of off-duty time can begin a new seven- or eight-day period, over which they can drive or be on duty a cumulative total of 60 or 70 hours respectively (i.e., the seven- or eight-day "clock" is restarted by a 34-hour off-duty period).
- As under Option 1, operators are limited to 11 hours of driving within a period of 14 consecutive hours from the start of the duty tour, followed by a break of 10 consecutive hours.

### 1.2.3 Option 3

This option is more stringent than Options 1 or 2, and essentially keeps the most restrictive features of the pre-2003 and 2003 HOS rules.

- Operators are limited to 10 (rather than 11) hours of driving within a period of 14 consecutive hours from the start of the duty tour, followed by a break of 10 consecutive hours.

- The use of split sleeper berth periods is eliminated – all 10-hour breaks must be consecutive, whether in a sleeper berth or not.

- As in Option 1, short-haul operators can be on-duty up to 16 consecutive hours one day during a seven-day work week so long as two such days do not occur consecutively. As in Option 2, however, operators of vehicles less than 26,000 lbs GVW, remaining within a 150 mile radius of their base, may keep timecards in lieu of logbooks and may be on-duty up to 16 consecutive hours two days during a seven-day work week

- Operators who obtain 58 consecutive hours of off-duty time can begin a new 7 or 8-day period, over which they can drive or be on duty a cumulative total of 60 or 70 hours (i.e., the 7/8-day "clock" is restarted by a 58-hour off-duty period).

### 1.2.4 Option 4

Finally, Option 4 is a variant on Option 3 which allows operators to restart the 7/8-day clock by taking a 44-hour off-duty period. It is intended to test whether the costs of virtually eliminating the restart can be mitigated while keeping some of the presumed fatigue-reducing benefits of a longer break.

## 1.3 BASELINE FOR THE ANALYSIS

This RIA compares the costs and benefits of the options relative to the rule that is currently in force – i.e., Option 1 – and assumes that there is full compliance with each of the options. This approach ensures that the full effects of the options' provisions on costs and benefits are captured. The pre-2003 rule was not used explicitly as a baseline in this analysis because a separate regulatory impact analysis was completed that measured the economic effects between a pre-2003 baseline and the 2003 rule. However, the effects of today's options can be compared to the pre-2003 rule using the effects reported in the Regulatory Impact Analysis for Hours of Service Options (the HOS RIA), prepared by ICF Consulting Inc. and Jack Faucett Associates, in December, 2002 (henceforth referred to as the 2003 RIA). That report, which is available in the HOS rule docket at http://dmses.dot.gov/docimages/pdf88/240882_web.pdf, assessed the effects of compliance with the 2003 rule relative to several other options. These options included a "Status Quo" option (i.e., the HOS rule that was in effect at the time of the analysis, assuming less than 100-percent compliance levels), as well as a "Current Rule/100%" option, which, similar to the current analysis, assumed full compliance with the pre-2003 rule.

## 1.4 OVERVIEW OF THE ANALYSIS

### 1.4.1 Assessing Costs

The analysis of costs recognizes that the different provisions of the options will affect carrier operations in complex and interacting ways. It also recognizes that these effects will depend strongly on the carriers' baseline operating patterns, which vary widely across this diverse industry. To produce a realistic measurement of the options' impacts, then, we divided the industry into broad segments, collected information on operations within these segments, and then created a model of carrier operations as they are affected by HOS rules. Given the very wide array of operational patterns, it was necessary to limit our analysis to the most important cases.

The model was first loaded with data representative of shipping patterns and carrier cost structures, and tested to ensure that it could realistically simulate typical lengths of haul, empty mile ratios, and productivity. It was then set up to cover most important cases, under constraints representing the options, and used to simulate carrier operations under different conditions and HOS rules. We then analyzed the data representing the simulated operations, using changes in miles driven as a measure of productivity impacts. Output measures from individual runs were weighted to give a realistic representation of the affected industry, including the drivers' use of the most important provisions of the options. The weighted changes in productivity from this procedure were then used to estimate the cost increases imposed on the industry by the options, using an analysis of the changes in wages and other costs likely to result from changes in productivity. These productivity-related costs were combined with transition costs associated with shifting to new rules to produce estimates of total social costs.

### 1.4.2 Assessing Benefits

Safety impacts were measured by feeding the working and driving schedules from the carrier simulation model into a fatigue model to project driver effectiveness levels, and then estimating the resulting changes in crash risks under different options for different cases. Changes in fatigue-related crash risks, calibrated to match realistic levels, were then multiplied by the value of all affected crashes to yield estimates of total benefits.

### 1.4.3 Assessing Impacts on Carriers

Finally, impacts on affected carriers were assessed using a pro-forma model of carrier operations for different carrier sizes, allowing for the effects of changes in driver wage rates and prices of trucking services.

## 1.5 REMAINING SECTIONS OF THE REPORT

The remainder of this report is divided into six additional chapters. Chapter 2 profiles the affected industry, in its qualitative characteristics and in terms of quantitative measures of firm sizes and the degree to which certain HOS provisions are currently used. Chapter 3 presents the methods used to estimate the effects of the options on industry operations, concentrating on the modeling of operational changes, and Chapter 4 then explains how these changes in operations were translated into changes in cost. Chapter 5 explains the translation of the operational changes into benefits. The results of the operational modeling, and the calculation of net costs and benefits, are presented in Chapter 6. Chapter 7 presents impacts on carriers (with emphasis on small entities), constituting the small business impact analysis.

Appendices are provided to expand on the data sources and calculations in several areas. (These appendices have been labeled with roman numerals in parentheses to avoid confusion with the appendices to the 2003 RIA (conducted for the 2003 HOS rule). Appendix (I) supports the industry profile in Chapter 2, Appendix (II) provides more detail on the simulation modeling described in Chapter 3, Appendix (III) describes recent studies on driving and fatigue, and Appendix (IV) provides more detail on the exemptions for smaller trucks used in short-haul service. Finally, the 2003 RIA is another important source of background material for this document; it is available at http://dmses.dot.gov/docimages/pdf88/240882_web.pdf

# 2. PROFILE OF THE AFFECTED INDUSTRY

## 2.1 OVERVIEW OF INDUSTRY SECTORS

The trucking industry is not homogeneous. Its various sectors are quite different from one another in their operating characteristics and, therefore, in the way in which they are affected by changes in HOS rules. In this section, we enumerate and describe the principal sectors and the distinctive ways in which they operate

### 2.1.1 General Description of Operations

In the following table are shown the principal sectors of the industry.

**Exhibit 2-1**
**Principal Sectors of Trucking Industry**

| **Over-the-road (OTR)** | **For-hire** | | **Private** |
|---|---|---|---|
| | Truckload (TL) | Less-than-truckload (LTL) | |
| **Local** | Local operations are treated as a single sector in this analysis. | | |

As the table shows, there are two main lines of division in the industry: one division is between private carriage of goods and for-hire carriage; the other is between carriage that is essentially local in character and carriage over longer distances (over-the-road (OTR)). Within OTR for-hire carriage, there is another major division—between truckload (TL) and less-than-truckload (LTL) operation. In OTR service, there are major differences among the operating characteristics of private carriage and the two types of for-hire carriage, and these differences have important implications for the effects of changes in HOS rules. In local operations, these differences, to a large degree, either disappear or cease to have much significance for HOS rules. This is why Exhibit 2-1 does not show separate sectors for local service. For reasons discussed later in this chapter, the HOS rule-change options under consideration would have limited impact on local trucking.

In the following sub-sections, we present and discuss operating practices and firm characteristics in the main sectors of OTR service; this is followed by a discussion of local service. First, however, we need further elucidation of the major sector distinctions shown in Exhibit 2-1.

**OTR vs. local service**

We may think of local service as movement among points within a metropolitan area, and to and from points within two or three hours' drive from that area.[3] In operational terms, one important difference between local and OTR service is the kind of work the driver does. In OTR service, driving is a driver's principal task. He will spend some time loading and unloading, and waiting to load or unload. The amount of time spent on loading and unloading will vary with length of

[3] As a point of demarcation, we use an average length of haul of 150 miles to distinguish local service from OTR service.

haul, types of customers, and types of service; but the preponderance of an OTR driver's time will be used for driving.

Local drivers will spend less time driving than OTR drivers. This is partly because they make many more stops to deliver or pick up goods or packages. It is also the case that many local drivers are not carrying goods, and their primary function is to perform a service, e.g., plumbing repairs, to which driving is ancillary. For these reasons, and others discussed below, none of the rule-change options (with the exception of the provision for vehicles from 10,000 to 26,000 pounds) will have a noticeable effect on short-haul trucking.

**For-hire vs. private carriage**

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

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

There are major operational differences between private and for-hire carriage; as a consequence, HOS rule changes will have different effects on these sectors. These differences will be discussed in more detail later. We should note here, however, that a major factor is the regular and repetitive character of private carriage that sets it apart from a large part of for-hire service. Regularity, or its absence, in drivers' schedules makes a significant difference in the effects of HOS rules. In general, regular operations will be less affected by the options under consideration.

**TL vs. LTL service**

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

An LTL company, by contrast, moves small shipments (typically in the range of 500 to 2,000 pounds) in a series of moves that involve both local and OTR operation. Local-service trucks pick up shipments from a number of shippers, bring them into terminals where they are consolidated into truckloads for OTR moves to other terminals, whence local-service trucks deliver individual shipments to their final destinations.

Regarding the impact of HOS rules, the major difference between for-hire TL and LTL operation is that LTL service operates on a regular basis, and most TL service does not.

Below, we present the following sub-sections on industry operations.

- TL operations
- LTL operations
- Private carriage
- Regular vs. random operation
- Team operations
- Local operations

### 2.1.2 Truckload Operations

The truckload business is an example of an industrial sector where something like atomistic competition actually prevails. This fact is reflected in the tight average operating ratio of this segment, 95.0 percent.[4] At a rough approximation, there are around 50,000 TL firms. Of these, 40,000 are very small, with five or fewer tractors[5]. This group is the owner-operators, those that are genuinely independent firms with their own customers. (There are over 300,000 owner-operators in total, but the great preponderance of them are working under lease to larger TL companies such that they are, in effect, part of the labor force of those companies and not firms seeking business for their own account.)[6]

As we see in Exhibit 2-2, small and middle-sized firms receive a very substantial share of total TL revenue. Assuming annual revenue of $125,000 per tractor, a company with 100 tractors has revenue of $12.5 million—not a large company.[7] But firms with fewer than 100 tractors have about 43.0 percent of sector revenue. A fleet of 500 tractors implies revenue of $62.5 million—no longer a small company but not a very large one. We see that firms with fewer than 500 tractors receive revenue of $75 billion—68 percent of total TL revenue.

**Exhibit 2-2**
**Truckload Revenue by Firm Size (in billions of dollars)**

| Size Class (Number of Tractors) | Revenue | Percent |
|---|---|---|
| 1 to 5 | 9.8 | 8.9% |
| 6 to 24 | 12.4 | 11.2% |
| 25 to 99 | 25.6 | 23.3% |
| 100 to 499 | 27.2 | 24.8% |
| 500 and more | 35.0 | 31.9% |
| Total | 110.0 | 100% |

Some of the operations of TL companies follow regular patterns, but some do not; we refer to the latter as "random" service. A truckload company in random service is analogous to a tramp-

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[4] Operating ratio is the ratio of operating cost to operating revenue.

[5] Virtually all OTR carriage is in tractor-trailer combinations, so tractors can be a measure of TL firm size.

[6] These and other estimates of industry size, revenues, etc., are based on the 2002 RIA, Appendix A.

[7] The methods and sources underlying these estimates are presented in the 2002 RIA, Appendix A.

steamer company in the ocean-freight business. The trucks do not operate on fixed routes and schedules; they go where the loads are. It is a bit difficult to generalize about operating patterns of TL firms. Some firms will concentrate in a particular region, some in very specific traffic lanes, and some will crisscross the nation, taking the best loads, in a business sense, as they find them.

Above some minimum size, a TL company will have one or more people whose task is to assign loads to drivers; this is the dispatch function. The dispatching staff live in a complex world, where they are constantly trying to make optimal decisions as to how to allocate their equipment and drivers to the available loads, bearing in mind a host of cost considerations, and, of course, HOS rules.

Regarding the independent owner-operators, companies with five or fewer tractors clearly cannot support either a sales force or a dispatch center. Typically, such companies function in one of two ways. Some of them will get their business from one or two customers with whom they have contracts, or less formal arrangements, to haul loads among a few points. Others may put their principal reliance on trucking brokers who provide, in effect, their marketing and dispatch functions. As companies increase above the minimal size, there will be at least one person giving most, or all, of his time to sales and dispatch, and then as revenues increase, there will be staff groups for these functions.

**Length of haul**

In the TL sector, "length of haul" is the distance from the point where a driver picks up a load to the point where he delivers the load. Average length of haul affects the impact of HOS rule changes. People in the truckload business make a distinction between regional and long-haul operations. A regional move is generally one of 500 miles or less, and a company calling itself regional would have an average length of haul under 500 miles or even a maximum of 500 miles. Many in the trucking business think of regional as same-day or next-morning delivery, a maximum of 500 miles. For our analysis, we have distinguished between short-regional, long-regional, and long-haul operations. On an average length-of-haul basis, we classify TL operations as follows:

| | |
|---|---|
| **Short-haul (local)** | <150 miles |
| **Long-haul** | |
| **Short regional** | 150-300 miles |
| **Long regional** | 300-700 miles |
| **Long haul** | >700 miles |

Trucking-firm behavior varies with length of haul, and these variations affect the impact of HOS rules. A driver in a regional operation, for example, is likely to have at least one pick-up and one drop-off in every day that he works. A long-haul driver will have days with only one pick-up or drop-off and days with neither in which he only drives. This difference affects the propensity to use the 11$^{th}$ hour. The less time a driver spends in loading and unloading, the more time he has available in the 14-hour window for driving. To the extent that he has more than ten hours available for driving, he is more likely to drive in the 11$^{th}$ hour.

### 2.1.3 Less-than-truckload operations

LTL companies are a sharp contrast with TL firms, both in degree of concentration and in mode of operation. Thirty-five companies receive 85 percent of sector revenue. While the LTL sector has a much higher degree of concentration than does the truckload business, it is, in total, much smaller than the TL world: just under one-third of TL revenue, perhaps ten percent of TL VMT. (See Exhibit 2-4 below.)

In order to operate its business, whether regional or national, an LTL firm requires a set of terminals. Each terminal will have a force of pick-up and delivery drivers. Typically, they go out in the morning with loaded trucks, make deliveries, spend the afternoon picking up loads, and return to the terminal at the end of the day with outbound loads. These loads are moved across the dock to outbound line-haul trailers. In a regional firm, these trailers will be pulled overnight to other terminals in the firm's network in time for delivery the following morning, when the pick-up and delivery cycle is repeated. Some loads may be going out of a carrier's region; they would be handed over to another LTL firm for onward movement to a destination at one of the other company's terminals.

For the national LTL firms, those that provide long-haul service and have average lengths of haul in excess of 1,000 miles, the operation is somewhat more complicated. These companies will have a set of major hub terminals, each of which is associated with a large number of satellite terminals. Line-haul moves will often be from satellite to hub and hub to satellite. In some circumstances, a trailer may go directly from a satellite to a hub in another region. Where the line-haul is more than 500 miles, moves are frequently handled with either teams or relays.

LTL trucking operates in a scheduled and routinized manner that is utterly different from the opportunistic journeys that comprise much of the business of a TL company. Many, if not most, LTL over-the-road drivers make the same run every night, and many of them never sleep away from home.

### 2.1.4 Private carriage

As noted above, private carriers are firms engaged in manufacturing and distribution that choose to carry their goods themselves. They do this because they believe they need direct control of the operation to ensure that tight schedule requirements are met, because they believe customer relations are enhanced when their own employees make deliveries, or for other reasons. Whatever the reason may be, private carriers incur a cost for moving their own goods. The alternative in most cases would be for-hire truckload service; private carriage is somewhat more costly than truckload—a premium of a little more than ten percent on a truck-mile basis.[8] Several factors may account for this difference: the high level of service that private carriers provide themselves which would include a higher ratio of empty miles to loaded miles; economies of specialization realized by truckload companies; and generally more generous pay-and-benefits packages for private drivers. Many private carriers try to offset this cost differential by seeking loads on a for-hire basis for their backhauls that would otherwise be empty.

[8] Transportation Technical Services, *America's Private Carriers*, 1999, p. 101.

It is difficult to generalize about private-carriage patterns of operation, as they have considerable variety. A firm may ship, for example, from a single national point to a small number of regional distribution centers (DCs) which, in turn, ship to a large number of stores or more DCs. Multiple drops are quite common: a driver leaves a factory or warehouse with a full trailer and makes several delivery stops before returning home. Some runs of this nature require the driver to spend several days on the road, just as a TL driver would. There will be other private operations in which the drivers never spend a night away from home.

We believe that, generally, private operations are much more of a scheduled and routine nature than is the case with random for-hire TL operations. Private carriage resembles LTL companies in this regard. We note that many TL companies are plagued with a very high rate of driver turnover; retention of drivers is a major issue in the TL sector. This is much less the case in LTL and private operations. Part of this stems from better pay and benefits in these latter sectors; part of this is because many of these companies either employ union drivers or must compete with employers of union drivers to obtain good drivers. But part of it is surely due to the irregular and often-shifting work times of TL operation.

Some private carriers arrange for this service on a contract basis; they outsource their carriage to a contractor, usually a truckload company that dedicates an agreed number of trucks and drivers to a private carrier's service. Since the equipment and drivers are under the control of the private carrier, such an operation behaves in the same way as any other private carrier.

### 2.1.5 Regular vs. Random Operations

An important aspect of trucking operations is regularity or the absence of regularity—the degree to which drivers repeat the same or similar routes and working hours over successive days and weeks. As noted earlier, a high degree of regularity tends to be the norm in private carriage and LTL firms. While this is also the case for some for-hire truckload service, a great deal of for-hire TL service is random. The distinction is important, especially for safety effects.

In random TL service, a company's trucks do not follow any fixed pattern. After a rest period at home, a driver picks up an outbound load near his home terminal and begins a road tour. Neither the driver nor the company's managers have any certain idea of where the driver will go after his first load is delivered. The company's sales force will do its best to find loads for him and keep him moving profitably until he completes his road tour and comes home. Most road tours will last from one to three weeks.

The defining characteristic of regular service is that it operates on predictable schedules; both managers and drivers know, with a high degree of certainty, what they are going to be doing. Regular service entails regularly repeating patterns. These may be fixed patterns where trucks follow the same series of origin-destination (O-D) pairs in the same sequence over the same time cycle. This could also be service from one or a few fixed origin points to a limited set of destinations in which loads are not moved over the same routes in a fixed sequence, but the operation is confined to that set of origins and destinations, and loads move between every O-D pair fairly frequently.

Much of the regular service in truckload companies is the dedicated service referred to above in the discussion of private carriage; this is simply out-sourced private carriage. It is often the case with these contracts that the shipper takes direct operational control of the dedicated fleet; other arrangements are also used. There are also in place contracts which provide for regular service but do not entail dedicated vehicles.

We have information on prevalence of regular service in the TL sector; we estimate it at 40.0 percent of TL VMT.[9]

One might suppose that regularity in operation would allow companies to plan schedules well within the limits of the HOS rules. Our industry experts[10] suggested that this is not necessarily the case; large customers may insist on schedules that leave little margin for error. We used data from an FMCSA survey[11] to test this proposition by comparing on-duty hours per tour of duty between regular and random drivers. We found little difference as seen in the following table.

**Exhibit 2-3**
**On-duty Hours—Regular vs. Random**
**Percentage of Tours of Duty[12]**

| On-duty Hours | Regular | Random |
|---|---|---|
| **14** | 3.2 | 2.5 |
| **13** | 5.6 | 5.4 |
| **12** | 12.4 | 13.5 |
| **11** | 16.3 | 15.3 |
| **<11** | 62.4 | 63.2 |

### 2.1.6 Team Operations

Team operation occurs in all the sectors discussed above—TL, LTL, and private carriage. These operations merit separate discussion, however, because they have some distinct operating characteristics regardless of which sector they are employed in.

The obvious difference between team and solo operation is that the former has two drivers in the cab and the latter has one. A solo tractor moves, at most, ten to 11 hours per day. A team tractor moves 20 hours per day. Even with driving in the 11th hour permitted, few teams achieve more than 20 hours per day. A variety of industry sources have told us that four hours or so of break time, with the truck stopped, out of 24 hours are necessary for most people.

The team drivers get their sleep in the berth with the truck moving most of the time they are sleeping. Unlike the case in solo operation, the drivers never sleep in a motel or truck stop as long as they are out on a road tour. As a result, rules on splitting sleeper-berth time need to be examined carefully to determine whether they may have a special impact on team drivers.

[9] Details underlying estimate are in Appendix (I).

[10] A group of trucking-industry experts assisted ICF in the conduct of this analysis. Their names are in Appendix (I).

[11] See sub-section 2.3.1 for explanation of this and other data sources.

[12] A tour of duty is the time from when a driver starts work to when he finishes work on a given day. It is the time constrained by the 14-hour rule.

By their very nature, teams are engaged in long-haul service. Further, two drivers means labor cost per mile is higher than solo operations; accordingly, companies will make every effort to keep teams moving. They will minimize waiting time for teams; not infrequently, if teams have to do loading or unloading, they will be paid by the hour for that work in addition to their per-mile payments.

Data on the extent of team use are not plentiful. In the 2003 RIA, we estimated that ten percent of OTR VMT was accounted for by teams. For this analysis, we have two additional data points on team drivers: interviews with eight TL and one LTL companies (mostly small firms) and information from a survey of its members done by the Owner Operator Independent Drivers Association. In the latter, 6.7 percent of drivers reported themselves as team members.[13] In the nine interviews, firms reported an average of 13.0 percent of drivers as team drivers.[14] Other anecdotal evidence suggests team drivers represent over ten percent of the driver workforce for the larger TL companies. For this analysis, we have assumed that 9.0 percent of VMT is accounted for by teams.

### 2.1.7 Local Operations

In general, short-haul trucking work has far more in common with “ordinary” work than it does with long-haul trucking. These are five-day-a-week jobs, and much of the time on duty is given to tasks other than driving. Typical work days are eight to ten hours or so and typical weeks are 45 to 55 hours. Many, if not most, of these drivers receive overtime pay past eight hours in a day. Most of the work is regular in character; drivers go basically to the same places and do the same things every day. The HOS rule changes now under consideration are likely to have little effect on such operations.

Short-haul and local operations may be affected by unforeseen circumstances and some operations definitely experience peak-load pressures, often on a predictable basis, which can cause some drivers to approach, and sometimes reach, the 14-hour on-duty limit. There will be occasions when the once-a-week 16-hour on-duty day is used.

Short-haul trucking includes both private and for-hire goods carriers and also services (plumbers, other repairmen, contractors) and utility functions (telephone and electric companies) that use trucks but carry no goods. Private carriage accounts for just over 60 percent of the local VMT generated by goods movement. (See Exhibit 2-5 below.)

Local private carriage is local deliveries of goods (including packages). In such service, a driver starts from a store or warehouse and makes a circuit of deliveries in the region, covering the same approximate route every day. Some of these could be large operations, e.g., a supermarket chain taking goods from warehouses to retail stores or liquor wholesalers delivering to stores and restaurants. Undoubtedly, much of it is also small operations such as florists or other specialty retailers.

The predominant form of local for-hire service is almost certainly pick-ups and deliveries of the package-express companies—UPS, FedEx, and others. Some of it is also the pick-ups and

[13] E-mail from John Siebert, OOIDA, May 11, 2005.

[14] Interviews conducted by George Edwards, one of the ICF team of industry experts.

deliveries of regional and national LTL firms. There are also some local LTL operations. Over 400 LTL companies list themselves as having average hauls of less than 150 miles.[15] We cannot be certain of the nature of all of these concerns. Some of the service they provide would be local LTL movement in the sense that actual origin and destination are within 150 miles of each other. A good part of their service would also be provision of pick-up and delivery service under contract with a larger LTL company that uses a local concern to avoid investing in a terminal in an area.

Local for-hire truckload service would include a variety of short freight moves. One ubiquitous example is tank trucks taking gasoline from storage facilities to gas stations. In many areas, there will be service hauling railroad-carried trailers and containers between rail yards and origins or destinations. There is a lot of auto-parts service in which parts and components are moved from the factories where they are made to assembly plants; many parts plants are well within 150 miles of assembly plants. We do not believe, however, that for-hire TL service is a large fraction of short-haul operations.

**Medium and Light-heavy Trucks (10,000 to 26,000 pounds)**

Since one of the rule-change options pertains to trucks in this size class, we note here that these vehicles are predominantly used in short-haul service. We estimate that 88.0 percent of the VMT of this size class are run in operation within 150 miles of their home bases. Indeed, over 60.0 percent occurs within 50 miles of home bases.[16] The percentage of short-haul VMT in commercial service is likely higher than this, because some of the longer-range movements must be accounted for by recreational vehicles.

## 2.2 SIZES OF SECTORS

The following table shows our estimates of VMT and revenue for the principal sectors of the trucking industry. The VMT numbers give some sense of the relative scale of operations in these sectors. In both short-haul and long-haul operations, private carriage is the largest single sector, and private carriage dominates short-haul service.

**Exhibit 2-4**
**OTR Revenue and VMT by Industry Sector**

| | Random TL | Regular TL | LTL | Private |
|---|---|---|---|---|
| Revenue (billions 2002$) | $58 | $39 | $27 | $123 |
| VMT (billions) | 46 | 31 | 8 | 81 |

[15] ICF, 2002 RIA, Appendix A, Exhibit A-2.

[16] Estimate based on 2002 Economic Census, Vehicle Inventory and Use Survey, Table 6. Details of the calculations are provided in Appendix (I).

**Exhibit 2-5**
**Local Revenue and VMT—For-hire and Private**

| (billions 2002$, VMT in billions) | For-hire | Private |
|---|---|---|
| **Revenue** | **$76** | **$122** |
| **VMT** | **30** | **50** |

NOTE: These estimates are from the 2003 RIA, Exhibit 3-1, p. 3-2. The only change is that truckload has been divided into regular and random service. Revenue figures for private carriage are imputed. Figures for short-haul and local are for carriage of goods; service and utility vehicles are not included. Full details on sources and calculations are in the 2003 RIA, Appendix A, pp. A-9-11.

## 2.3 WORK PATTERNS

In the following sub-sections, we examine patterns of working by drivers in the different sectors of the trucking industry. In particular, we are interested in intensity of effort; this may be thought of as the degree to which drivers work close to the limits imposed by the HOS rules. We can look at this in terms of hours worked (on-duty hours) in a week and in a day, hours driven in a day, days worked and days off in a week. These measures are important for analysis of both productivity and safety effects of rule changes. In developing values for these measures, primary emphasis was placed on OTR service. Some comparable data for short-haul operations are reported in a separate sub-section.

### 2.3.1 Data sources

The measures of work patterns and intensity presented in this section are based on several principal data sources. For the most part, these sources provide information on for-hire TL, OTR operations. We have four sets of data on current experience (under the 2003 HOS rule): data provided by Schneider National on some aspects of its operations; data from the Owner Operator Independent Drivers Association (OOIDA) based on a survey of its members; a survey of private carriers carried out by Professor Stephen Burks of the University of Minnesota; and data collected by FMCSA (the “field survey”). The Schneider, OOIDA, and Burks data were gathered with the express purpose of obtaining information on use of three aspects of the new rule: the 11th hour, restarts, and split sleeper periods.

Each of these sources is focused on a different sector of the industry. Schneider’s data are about a large TL firm. OOIDA data are based on owner-operators and a small number of company drivers for TL firms. The field-survey data largely represent company drivers with small TL companies. In terms of distribution of company size, this makes sense; the great preponderance of TL companies are quite small. In the field survey, 86 percent of for-hire, TL/OTR companies have fewer than 25 tractors. In ICF’s profile of the industry in the 2003 RIA, we estimated that 87 percent of such companies had fewer than 25 tractors. But these small companies account for a fairly small share of TL/OTR VMT—17.0 percent.[17] Viewed in terms of truckload company size, the field survey is a representative sample, but these companies account for a small share of

[17] Calculation from data in ICF, 2002 RIA, Appendix A, Exhibit A-2.

total trucking activity. LTL firms and private carriers are sparsely represented in the field survey. Following is some more specific information on each of these sources.

**Schneider**

These data cover approximately 16,000 drivers. They were taken from company records for August and October of 2004.

**OOIDA**

OOIDA posted a survey form on its website asking drivers for information on use of the new-rule features in the month of June 2004. The data used here are based on responses from 1,223 drivers.

**Burks**

Professor Burks mailed a survey form to private carriers asking for information on their drivers' use of the new-rule features in the month of June 2004. He received usable responses from 29 firms covering 3,311 drivers.

**FMCSA Field Survey**

These data, based on drivers' log books, were obtained from companies in the course of compliance reviews or safety audits. Data cover 542 drivers with 269 firms in the period July 2004 to January 2005. For each driver, data for one month of operation were collected.

In addition to the above data, George Edwards, a member of our team of industry experts, interviewed a number of trucking firms. Information from nine of his interviews was used here; these were eight small TL firms and one small LTL firm.

### 2.3.2 Average hours per day—on-duty and driving

Two basic measures of work are daily hours of driving and total work, the latter term including all on-duty time, both driving and other work. The field survey and the Schneider data provide information on driving time per tour; only the field survey provides data on on-duty hours per tour. The field survey provides some information on local drivers; the Schneider data do not distinguish between local and OTR operations.

A basic assumption in the calculation is that a day is equivalent to a tour of duty. While there are exceptions, the great preponderance of drivers work one shift in a day. A tour of duty comprises the time from the driver's start of work to end of work, including driving, other on-duty, and off-duty time. Results are in Exhibit 2-6. That the numbers for driving hours for Schneider and OTR drivers from the field survey are so close enhances confidence in these numbers, even though the Schneider data include local service along with OTR operation.

**Exhibit 2-6**
**Daily driving and on-duty hours—averages**

| | Field Survey | Schneider |
|---|---|---|
| **Driving** | 7.7 | 7.6 |
| **On-duty** | 9.2 | N/A |

NOTE: The field survey is our only source for on-duty hours in tours of duty.

### 2.3.3 Average hours and days of work per week

For OTR drivers, a typical measure of work is number of hours in eight days; that tells us how close drivers work to the 70-hour limit for eight days. A more complete understanding of drivers' work patterns, though, is revealed by examining data on days worked per week. We can calculate this latter measure from both the field survey and the Schneider data.

Both sources give us hours worked in eight days—62 hours for Schneider drivers, 59 hours for field-survey drivers.[18] Some intermediate steps are required to convert these numbers to days per week. We divide them by 9.2 (the field-survey figure for on-duty hours per tour of duty) to obtain days worked per eight days and then make a further adjustment to obtain days worked per seven days. These results are presented in Exhibit 2-7.

**Exhibit 2-7**
**Average Weekly Hours and Days Worked**

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

### 2.3.4 Degree of intensity of effort

Were we to look only at the averages shown above for hours of driving and hours and days of work, we might conclude that all drivers work well within the limits imposed by the HOS rules (not allowing for non-compliance). This is, of course, not the case; many drivers work and drive longer hours than the averages. We need to know the percentages of drivers that work close to the limits; this information is important for estimating both productivity and safety effects of a new rule. This information is summarized in the following exhibits on daily driving and on-duty hours and on-duty hours in 8-day periods.

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

**Exhibit 2-8**
**Driving Hours Per Tour of Duty**

| Driving Hours | Percentage of Tours | | |
|---|---|---|---|
| | Schneider | Field Survey | OOIDA |
| 11 | 10.7 | 16.2 | 28.0 |
| 10 | 15.5 | 16.1 | N/A |
| 9 | 16.4 | 11.2 | N/A |
| <9 | 57.4 | 56.5 | N/A |

NOTE: OOIDA data was collected on a different basis from those of the other sources. The OOIDA survey asked for frequency of use of the 11$^{th}$ hour but did not otherwise ask about driving hours. ICF calculated the OOIDA number shown here from the underlying survey data.

It is worth noting that the on-duty hours show a pattern relative to the 14-hour limit different from that of the driving hours relative to the 11-hour limit. Drivers are driving ten or more hours in more than 25.0 percent of their work days while reporting 13 or more on-duty hours for only 8.0 percent of days. The latter number suggests that drivers are generally taking two hours of break in a 14-hour tour or their normal work shifts are shorter than 14 hours. We suspect that both are true. Inaccurate logging of on-duty hours could also be a factor.

**Exhibit 2-9**
**On-duty Hours Per Tour of Duty (Field Survey Only)**

| On-duty Hours | Percentage of Tours |
|---|---|
| 14 | 2.7 |
| 13 | 5.5 |
| 12 | 13.2 |
| 11 | 15.6 |
| <11 | 63.0 |

From Exhibits 2-9 and 2-10, we see that, while daily on-duty hours tend to “bunch” away from the limit, multi-day on-duty hours bunch close to the limit, closer, indeed, than is the case for driving hours. Exhibits 2-8 and 2-10 give us some information on differences in behavior between company drivers and owner-operators. While driving hours show a marked difference, the difference in multi-day hours is slight. Some of this could be accounted for by the fact that OOIDA’s data include some owner-operators working on their own authority; those in the Schneider data are all leased.

**Exhibit 2-10**
**On-duty Hours in 8-day Periods**

| On-duty Hours | Percentage of 8-day Periods | | |
|---|---|---|---|
| | Schneider | | Field Survey |
| | Company | Leased | All TL |
| >64 | 41.0 | 41.3 | 26.3 |
| 60-64 | 23.5 | 25.7 | 16.6 |
| 50-59 | 35.6 | 33.1 | 57.1 |

Regarding differences in the average driving hours listed in Exhibit 2-8, it should be noted that there are few owner-operators in the field-survey data; the higher percentage of 11$^{th}$-hour use from the field survey, as compared with Schneider, suggests that smaller companies may push harder than larger ones, insofar as the driving limit is concerned. The OOIDA data on the 11$^{th}$ hour could be seen as part of such a pattern, especially if we think the own-authority owner-operators are using the 11$^{th}$ hour heavily. On the other hand, the multi-day hours show the reverse pattern. For 65.0 percent of reported instances, Schneider's drivers have over 59 hours; from the field survey, the comparable number is 43.0 percent. This might suggest that a big company does not schedule as close to the driving limits as a smaller company might but enjoys greater success in marketing and, thus, is able to keep its drivers moving more consistently. There could, of course, be other explanations.

In general, we must be wary of reaching too far in drawing inferences from these data. To the extent, however, that data from different sources show consistent patterns, we can use this information in our analysis with some confidence. One pattern that comes through consistently is that the preponderance of OTR drivers and trucking firms are not operating at, or close to, the HOS limits. On an approximate basis, we could say that 25 to more than 30 percent of drivers are driving more than nine hours regularly and 25 to 40 percent of drivers are regularly working more than 64 hours in eight days. Put another way, 70 to 75 percent of drivers do not go past the ninth hour and 60 to 75 percent work fewer than 65 hours in a given eight day period. The industry experts with whom we consulted throughout the study said that this is an accurate general view of industry operations.

### 2.3.5 Local Operations

In general, short-haul trucking is more regular and less intense relative to the HOS rules than OTR trucking. The greater regularity can be seen in the times at which local drivers start and finish work compared to the same times for OTR drivers. The field survey gives us data with which to make this comparison. Exhibit 2-11 shows that a much higher proportion of local drivers are working "normal" days.

**Exhibit 2-11**
**Times for Starting and Stopping Work**

| | OTR | Local |
|---|---|---|
| **Percent starting 6-8 AM** | 28.8 | 63.3 |
| **Percent stopping 4-6 PM** | 26.4 | 57.4 |

Exhibit 2-12, 2,-13, 2-14 compare the hours driven and worked, days worked, and intensity of effort of local with OTR service by repeating Exhibits 2-8, 2-9, and 2-10 with an added column for local service.  Exhibit 2-12 shows that the averages for daily hours and weekly days in local service are only slightly less than those for OTR service.  But, as we see in Exhibits 2-13 and 2-14, comparison on the basis of hours worked near the HOS limits demonstrates that the great preponderance of local operations stay well within those limits.

**Exhibit 2-12**
**Average Hours per Day and Days per Week**

| | Field Survey | Schneider | Local |
|---|---|---|---|
| **Driving hours** | 7.7 | 7.6 | 6.4 |
| **On-duty hours** | 9.2 | N/A | 9.1 |
| **Days/week** | 5.6 | 5.9 | 5.5 |

NOTE: Number for local days/week come from a Virginia Tech Transportation Institute survey of short-haul drivers ("Impact of Local/Short Haul Operations on Driver Fatigue, Virginia Polytechnic Institute and State University, 2000).

Exhibits 2-13 and 2-14 show, respectively, driving hours and on-duty hours distributed over the number of hours worked or driven. Perhaps the key numbers in these tables are in the bottom rows. We see that 77.3 percent of local drivers drive fewer than nine hours in a tour compared to 57.4 percent of OTR drivers; the same comparison for drivers working fewer than 11 hours (Exhibit 2-14) shows 72.8 percent for local service and 63.0 percent for OTR operations.

**Exhibit 2-13**
**Driving Hours per Tour of Duty**

| Driving Hours | Percentage of Tours | | | |
|---|---|---|---|---|
| | Schneider | OOIDA | Field Survey (OTR) | Local |
| 11 | 10.7 | 28.0 | 16.2 | 5.6 |
| 10 | 15.5 | N/A | 16.1 | 5.2 |
| 9 | 16.4 | N/A | 11.2 | 11.8 |
| <9 | 57.4 | N/A | 56.5 | 77.3 |

**Exhibit 2-14**
**On-duty Hours per Tour of Duty**

| On-duty Hours | Percentage of Tours | |
|---|---|---|
| | OTR | Local |
| 14 | 2.7 | 2.5 |
| 13 | 5.5 | 4.2 |
| 12 | 13.2 | 10.7 |
| 11 | 15.6 | 9.8 |
| <11 | 63.0 | 72.8 |

## 2.4 USE OF FEATURES OF 2003 RULE

We examined the use of three aspects of the 2003 rule: restarts, the $11^{th}$ hour, and the split sleeper-berth provision. The data come from the sources already mentioned: Schneider, OOIDA, Burks, and the FMCSA field survey. These sources were supplemented by anecdotal information from George Edwards's interviews and discussions with other members of our industry-expert team.

### 2.4.1 Restarts

All four of our data sources reported on use of restarts. OOIDA reported that almost ninety percent of drivers used the restart at least some of the time.[19] Burks reported that private carrier drivers in his survey used the restart on 61.0 percent of their runs.[20] Neither OOIDA nor Burks, however, reported on length of restarts. It soon becomes clear when looking at other data and from discussions with industry experts that, when a driver says he used the restart provision, he does not mean he took only 34 hours for the restart period. What he means is that he used the restart rule to calculate the time at which he could go back to work; drivers find the method of calculation far simpler than trying to keep track of on-duty hours in a moving eight-day period. They only have to count the hours from the last restart to know when they are approaching the 70-hour limit. Once they decide to go into restart, they only have to count the hours from that point forward to know when they may go back on duty.

Schneider and the field survey both reported a high level of use of restarts and gave information on the length of restarts. In Schneider's data, only 2.0 percent of restarts were only 34 hours. Depending on the reporting period, one-quarter to one-third of the restarts were 44 hours or fewer. Forty-three percent were 58 hours or fewer. Schneider showed a bi-modal distribution with peaks at 39 and 62 hours. Presumably, the former reflects cases in which the driver has taken one full day off, plus a few hours from the preceding and following days; the latter would reflect two full days off, presumably at home.

From the field survey, we see 33.0 percent of restarts were 44 hours or fewer. This comports well with the Schneider data. On this basis, we can say that at least one-third of restarts are short enough to bring a productivity gain. Using the alternative method of the moving eight-day period, drivers would usually have to stay off more than 44 hours before returning to work.

Our anecdotal information on company attitudes towards restarts is that they like the provision and find some productivity gain even though drivers are staying off more than 34 hours. Managers seem hesitant to demand a return to work after 34 hours, except in unusual situations. It may, of course, be the case that taking only 34 hours off would not fit with the work schedule of many drivers, i.e., there would not be anything for them to do at the 35$^{th}$ hour. For example, the 35$^{th}$ hour might come at 3:00 AM, and the company might have no use for the driver until 8:00 AM. When a TL driver comes off his restart, his first task is to pick up a new load; the hour at which the company needs his services will be set by the requirements of the shipper of that first load.

### 2.4.2 Split Sleeper-berth Periods

The dominant message from the data is that most drivers never split, and those that do split do so only occasionally. Schneider's data for October 2004 show 97.0 percent of drivers never splitting and only 0.4 percent splitting "regularly." We need to bear in mind that, before the new rule,

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[19] John H. Siebert, "A Survey of Owner-Operators and Company Drivers on their Use of Three New 'Hours of Service Features,'" OOIDA Foundation, September 15, 2004.

[20] Stephen V. Burks, A Survey of Private Fleets on their Use of Three New 'Hours of Service Features,'" September 15, 2004

Schneider did not allow solo drivers to split at all and has only allowed them to split on an 8-and-2 basis under the new rule.

The data from OOIDA and the field survey show many more drivers splitting occasionally but few splitting frequently. We see this in the following table.

**Exhibit 2-15**
**Incidence of Splitting**

| Splitting frequency | Field Survey | OOIDA |
|---|---|---|
| **0 times per month** | **66%** | **55%** |
| **1-4 times per month** | **20%** | **20%** |
| **0-4 times per month (sum of above rows)** | **86%** | **75%** |
| **Average percent splitting per day** | **6%** | **13%** |

Information from the Burks survey suggests a higher percentage of frequent splitting. The Burks data are not directly comparable with those from the field survey and OOIDA. They suggest that 52.0 percent of drivers split four or fewer times a month with the rest splitting more frequently. We think that is a correct general interpretation, but we are not sure. It is not clear why private drivers would split more frequently than others. There might be a higher percentage of teams in Burks's data; we do have evidence that teams split more frequently than solo drivers.[21]

The data in the following table come from an Insurance Institute for Highway Safety (IIHS) survey of drivers at weigh stations in Pennsylvania and Oregon and from FMCSA'a Driver Fatigue, Alertness and Countermeasures Study (DFACS).

**Exhibit 2-16**
**Incidence of Splitting—Team and Solo**
**(percentage of drivers who say they split sometimes)**

| | IIHS | DFACS |
|---|---|---|
| **Solo** | **24** | **22** |
| **Team** | **47** | **52** |

Given the agreement between the IIHS and DFACS findings, we are safe in saying teams split more than solo drivers. Intuitively, that is what one would expect. There is some anecdotal evidence that the incidence of splitting by teams is higher than that found by IIHS and DFACS. A number of comments to the docket suggested higher percentages than these and also indicated that team splitting is generally balanced; that is, sleeper periods and driving stints are about equal at four to six hours each.[22] We also note that the IIHS/DFACS findings for solo drivers sometimes splitting are lower than those from OOIDA and the field survey.

[21] There is also some ambiguity in the Burks survey which asked for the percentage of "runs" using the splitting rule but did not define runs. It appears that some respondents interpreted "run" to be a multi-day period. In the field survey data, we saw instances in which drivers reported splitting, though one of the "split" rest periods exceeded ten hours. We discarded these cases, but this shows the danger of inaccurate logging of split sleeper periods.

[22] Docket 19608; see comments by Yellow-Roadway, FedEx, CR England, Overnite, ATA, MCFA.

What the data on splitting clearly tell us is that splitting for most solo drivers occurs on an occasional and opportunistic basis. They do not build splitting into their operating routines. When they do take a split period in the sleeper, they go right back to the ten-hour rest at the next rest period. This does suggest that most drivers find the limited rest period unsatisfactory and use it only to avoid some other problem. An unexpected period of congestion would be one example. On the other hand, routine splitting is probably part of the daily operation of many teams.

Anecdotal information from the Edwards interviews is that managers dislike splitting for solos, do not encourage it, but do not forbid it outright.

### 2.4.3 The 11th Hour

The following table summarizes our findings on 11th hour use.

**Exhibit 2-17**
**Incidence of 11th Hour Use**
**(percentage of tours or runs on which used)**

| Schneider | OOIDA | Field Survey | Burks |
|---|---|---|---|
| 10.4 | 28.0 | 16.2 | 31.0 |

Note: Field-survey numbers for compliant drivers only. Burks data might overstate 11th hour use because of previously noted ambiguity about meaning of "run."

These findings tell us that the 11th hour is definitely being used. As between Schneider, OOIDA, and the field survey, there is certainly an implication that big companies use it less often than small companies or owner-operators. That is plausible on the supposition that small firms push closer to the limits than large ones do. Some of the data we have adduced in this chapter certainly suggests that, though we are using data for only one large company.

In any event, in estimating overall use of the 11th hour, we have proceeded on the basis that usage is heavier for smaller firms. For this purpose, we chose to use 25 tractors as the point of demarcation between big and small truckload companies. We estimate that 40.0 percent of TL VMT is from small companies and 60.0 percent is from large companies.[23]

The high percentage for the private carriers may have several explanations. One possibility is that the 29 companies reporting are not representative. But we note that many of the responding companies have long runs; they may be building the 11th hour into their schedules. Some of the information from the Edwards interviews tells us that LTL managers are now planning some runs that use the 11th hour. This would occur, for example, when a company finds that use of the 11th hour would bring one or more additional terminals within the overnight reach of a given terminal. If LTL managers are thinking that way, one would expect to find the same thing with private-fleet managers. They, too, have systems with a fixed set of nodes (factories, warehouses, etc.); if they find that the 11th hour brings one more warehouse within a day's trip from a factory, for example, they are likely to take advantage of it.

[23] Calculation from data in ICF 2002 RIA, Appendix A, Exhibit A-2.

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# 3. ASSESSMENT OF IMPACTS ON OPERATIONS

## 3.1 OVERVIEW OF ANALYSIS OF IMPACTS ON CARRIER OPERATIONS

As discussed in Chapter 2, the most important segments of the industry that will be affected by the options include solo TL for-hire drivers with random schedules, solo TL for-hire drivers with regular schedules, and solo TL private fleet drivers. Their complex patterns of operation, and the difficulty of estimating how the various provisions might interact in their effects on productivity and safety, led us to develop a simulation-based approach to analyzing these segments. We judged simulation to be more able to generate realistic combinations of behaviors than scenario-based analyses, and therefore better able to illuminate the true effects of the options.

Two other significant segments are solo LTL drivers, and team drivers. The smaller scale of the LTL segment, and the fact that its drivers tend to follow very regular schedules, led us to represent it using the results of the simulation of regular TL drivers. Because team drivers are known to be favored only in intensive long-range operations, and need to follow regular schedules, we determined that they could best be assessed using simple scenarios.

## 3.2 SIMULATING IMPACTS ON COMPLEX CARRIER OPERATIONS

In the simulation model used to assess impacts on the more complex types of carrier operations, a truck's progress is tracked in a computer program as the driver moves between origin and destination points, choosing new loads at the end of each run from a set of choices randomly selected from a data base representative of inter-county shipment patterns. The driver's choices are made on the basis of which loads feasibly can be picked up and delivered within specified windows, given the limits imposed by the need to stop and rest. Within feasible choices, the driver is assumed to choose (or be assigned) the load that is most advantageous in terms of its contribution to its productivity. Because the HOS rules affect which loads can be delivered, and change the amount of time that can be devoted to driving, the model is able to estimate impacts on productivity, and the accompanying changes in typical schedules.

To implement this approach, ICF developed an Excel macro-driven simulation model to simulate a commercial vehicle driver (CMV) operating in compliance with HOS regulations. The HOS simulation model simulates how a CMV operator would behave, starting from its home terminal and making various stops to pick up and deliver shipments over a pre-defined duration. The regulations are defined by the user so the model can analyze various types of HOS options to show a marginal impact of a specific regulation (e.g., adding one more hour to the daily limit on driving hours).

**Exhibit 3-1**
**Operation Cycle of HOS Model**

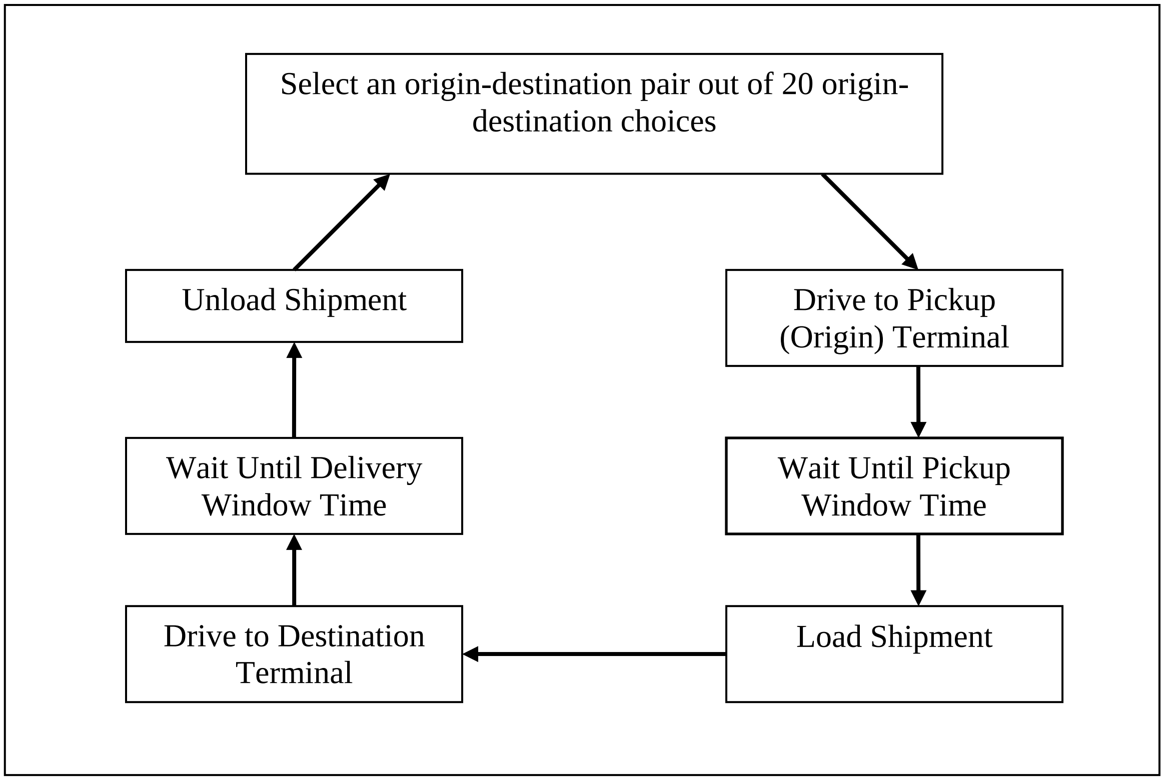


Exhibit 3-1 shows the operation cycle of the simulation model. The model starts at the user defined home terminal. Out of 20 randomly generated origin-destination pairs, it chooses the pair that best fits its schedule as well as maximizes its productivity. Then it moves to the origin terminal, waits until the pick up window time, and loads the shipment. It then drives to the destination terminal, waits until the delivery window time, and unloads the shipment. At this point, the model again analyzes another set of 20 origin-destination pairs and repeats the same procedure prescribed above for the time duration defined by the user. The movement of the truck in the model is constrained by HOS rules (i.e., all required rest periods) allowing the user to compare different facets of HOS rules with assumption of full compliance.

At the end of the simulation, the model yields an output that shows how the CMV operator behaved at each time of day. The truck's movement following the operation cycle is recorded in the schedule output table which reveals what the truck was doing at each time of the day each day during the whole simulation duration. The duration of simulation is defined by the user so the model can generate up to one year's worth of the schedule table. Exhibit 3-2 is a snapshot of the schedule table showing only a small portion of it. The table actually has over 40 columns providing details such as time of the day, day of the week, driving status, load status, origin county, destination county, cumulative duty, driving, and rest hours.

**Exhibit 3-2**
**Schedule Output of HOS Model**

| Trip Day | Time of Day (24HR Format) | Day of the Week | Status | Load Status | Origin | Destn | Driving HRS Until Arrival | Load Time | Unload Time | Dummy Rest | Dummy On-duty | Dummy Driving | Cumulative On-Duty HRS | Cumulative Driving HRS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7.00 | MON | REST | EMPTY | 17,031 | 17,031 | 1.00 | 2.00 | 3.00 | 0 | 0 | 0 | - | - |
| 1 | 7.50 | MON | DRIVE | EMPTY | 17,031 | 17,031 | 0.50 | 2.00 | 3.00 | 0 | 1 | 1 | 0.50 | 0.50 |
| 1 | 8.00 | MON | DRIVE | EMPTY | 17,031 | 17,031 | - | 2.00 | 3.00 | 0 | 1 | 1 | 1.00 | 1.00 |
| 1 | 8.50 | MON | LOAD | FULL | 17,031 | 5,045 | 11.00 | 2.00 | 3.00 | 0 | 1 | 0 | 1.50 | 1.00 |
| 1 | 9.00 | MON | LOAD | FULL | 17,031 | 5,045 | 11.00 | 2.00 | 3.00 | 0 | 1 | 0 | 2.00 | 1.00 |
| 1 | 9.50 | MON | LOAD | FULL | 17,031 | 5,045 | 11.00 | 2.00 | 3.00 | 0 | 1 | 0 | 2.50 | 1.00 |
| 1 | 10.00 | MON | LOAD | FULL | 17,031 | 5,045 | 11.00 | 2.00 | 3.00 | 0 | 1 | 0 | 3.00 | 1.00 |
| 1 | 10.50 | MON | DRIVE | FULL | 17,031 | 5,045 | 10.50 | 2.00 | 3.00 | 0 | 1 | 1 | 3.50 | 1.50 |
| 1 | 11.00 | MON | DRIVE | FULL | 17,031 | 5,045 | 10.00 | 2.00 | 3.00 | 0 | 1 | 1 | 4.00 | 2.00 |
| 1 | 11.50 | MON | DRIVE | FULL | 17,031 | 5,045 | 9.50 | 2.00 | 3.00 | 0 | 1 | 1 | 4.50 | 2.50 |
| 1 | 12.00 | MON | DRIVE | FULL | 17,031 | 5,045 | 9.00 | 2.00 | 3.00 | 0 | 1 | 1 | 5.00 | 3.00 |
| 1 | 12.50 | MON | DRIVE | FULL | 17,031 | 5,045 | 8.50 | 2.00 | 3.00 | 0 | 1 | 1 | 5.50 | 3.50 |

In the following sections, more detailed description of the set-up and operation of the model is presented.

### 3.2.1 Assumptions

#### User-Defined Assumptions

In the user interface page of the model, the user defines the HOS option to be simulated. The HOS option is modeled by imposing maximum duty, maximum driving, and minimum rest hours per day, minimum restart rest hours, and maximum duty hours in the last 8 days. The model is designed to be sensitive to each of these different assumptions in order to analyze the marginal impacts of any single facet of HOS regulation under different simulation settings.

The user enters the following assumptions:

Maximum duty hours in a day

- *Maximum driving hours in a day*
- *Minimum rest hours in a day*
- *Maximum duty hours since a restart rest period in the last 8 days*
- *Minimum rest hours for a restart rest period*
- *Home terminal county*
  The county where the CMV operator's home terminal is located. The simulation starts from this county.
- *Operating region limit*
  The maximum distance the CMV operator considers for potential shipment pick-ups. For example, if the operating region limit is the default of 100 miles, the CMV

operator only considers available pick-ups from terminals located within 100 miles of its present location.

- *Minimum shipment miles*
  The minimum miles from origin to destination that the CMV operator considers for a shipment.

- *Maximum shipment miles*
  The maximum miles from origin to destination that the CMV operator considers for a shipment

- *Average speed*
  The speed of the truck during driving hours – the default is 50 mph.

- *Minimum sleeper hours*
  The minimum duration of a split rest period, using a sleeper berth. This is equal to 10 when simulating an option that does not allow any splitting of rest periods.

- *Region*
  Which of four continental U.S. regions the model will simulate: Northeast, Midwest, West, and South.[24]

- *Time increment*
  Increment of time increments, either 15 or 30 minutes, after each of which the model simulates a possible new decision and change in activity (drive, rest, load, or unload) for the CMV operator.

- *Duration for the analysis*
  The user can choose for the simulation to cover a time period of 3, 6, or 12 months.

**Default Assumptions**

In addition to the assumptions that can be revised by the user, the model has a number of default assumptions. These are detailed in Appendix (II), and enumerated below:

- *Loading and Unloading Time* – The time required for loading and unloading the vehicle.

- *Pick-up Day of Week* – The distribution of the day of the week for shipment pick-ups, which is that pick-up days are basically evenly distributed for the weekdays while the weekends are rarely used.

- *Delivery Day of Week* – The scheduled delivery day of the week, which depends on the pick-up day of week and the travel time required to the delivery destination.

[24] See the Appendix for a definition of the regions.

- *Pick-up and Delivery Windows* – The pick-up and delivery windows represent the interval of time in which a pick-up or interval needs to be made

### 3.2.2 Model Operation

The model starts at a user-defined home terminal and selects (using a utility function[25]) the next shipment to be carried from an array of 20 randomly generated origin-destination pairs. In addition to an origin and destination, each shipment has characteristics randomly generated to simulate the pick-up terminal, destination terminal, the pick-up and delivery days of week, pick-up and delivery terminal hours of operation, and scheduled windows for pick-up and delivery.

The origin terminals are randomly drawn from the set of all terminals that are within 100 miles of the CMV operator's current location (the home terminal for the first trip). The destination terminal for each origin is then randomly drawn based on recent data on the probabilities of various origin-destination pairs (a more detailed exposition is presented in section 3.2.3 Order Sets). The seven origin-destination pairs with the earliest feasible pick-up times are evaluated to choose the shipment with the highest utility.[26]

The model runs a simulation of each of the seven O-D pairs and yields schedule output for each O-D pair.[27] The schedule output shows how the CMV operator would behave in each 15 or 30-minute time increment (whether the driver drives, rests, loads, or unloads), until the vehicle arrives at the destination. By listing the CMV operator's action in each time increment, the model can analyze whether the CMV operator is able to meet the pick-up and delivery windows and how efficiently the CMV operator is moving to the destination. If it is simulated that the CMV operator cannot meet the pick-up or delivery time windows, the model designates zero utility to that particular O-D pair and moves on to simulate the next O-D pair. When the simulations for the first seven feasible pairs are done, the model selects the origin-destination pair with the highest utility and writes its schedule output to an output table that shows the CMV operator's behavior.

Once the CMV operator arrives at the destination, the process begins again as the CMV operator is presented with another 20 origin-destination pairs and the model simulates the top seven pairs again. Thus, the model repeats the process of simulating the top seven origin-destination pairs, selecting the pair with highest utility, and writing the selected O-D pair's schedule output to the output table until the duration of the output reaches the duration defined by user in the summary page.

In summary, the driver follows the pattern of operation shown in Exhibit 3-1.

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[25] A detailed exposition on the utility function, which incorporates direct and indirect economic costs and non-monetary desires, is presented in Section 3.2.4 and in Appendix (II).

[26] The model thus discards the other 13 pairs because they were infeasible or otherwise presumed to lead to lower utility. While theoretically not necessarily true, it is believed that this type of practical rule of thumb is an accurate simulation of actual CMV operator behavior.

[27] In a few cases, none of the 20 origin-destination pairs that the CMV operator faces are initially feasible. Please see the Model Operation Note in the Appendix for how this is addressed.

### 3.2.3 Order Sets

The process of obtaining a representative sample of the US truck transportation industry's movements began by obtaining data sets containing the total tons shipped to and from every county in the country, sorted by FIPS code[28]. It was decided to base the sample on the total tons shipped to and from each county to best represent the number of truckload moves. The shipments to and from each county were combined to create a table relating each county to the total tons shipped associated with it. This data set provided 3,141 data points from which to create a sample. This data set was then simplified to a sample size of 1,000, to speed model computation time, using a method that insured freight movement patterns were maintained with correct geographic representation and a mix of small and large counties. Details of this method are provided in Appendix (II).

### 3.2.4 Utility Function

For those segments of the industry (long-haul and regional random truckload) for which the simulation selected the next shipment immediately following the completion of the previous shipment, a utility function was used to simulate the next shipment decision. The utility function was used to monetize the total value of each of the shipment alternatives available to the driver at the decision moment. The utility function included the monetary operating costs of the vehicle, labor and labor-related costs, capital costs, revenue to be earned, and monetized penalties for the driver's time and distance away from its home and the driver's status in terms of working hours remaining before fulfillment of the 70 hour work limit.

For each available alternative of a shipment from an origin "O" to a destination "D", several total utilities were calculated (and expressed in dollars), based on the different choices the driver could make regarding resting, waiting, or driving prior to actual pick-up of the shipment. The different alternative work schedules within each origin-destination shipment were compared to determine the highest utility available for a given shipment. The different alternative shipments were then compared, with the driver assigned to perform the shipment with the highest calculated utility.

The full details including the specification and cost elements of the utility function are included in Appendix (II).

### 3.2.5 Algorithms

In addition to the model operation components more generally described above, a number of algorithms were used to carry out some of the specific model components. These are detailed in Appendix (II), and enumerated below.

***Destination Algorithm* -** The shipments' origins and destinations are based on recent empirical data regarding the actual probabilities of commercial truck movement from county to county in the continental United States.

[28] FIPS codes generally represent counties, parishes or districts. The term county is used interchangeably herein to also represent FIPS code areas, parishes and districts.

***Load Choice Algorithm*** **-** As explained in the operation section (3.2.2), the model allows the user to see actual behavioral pattern of the driver in each of 15 or 30 minute time slots as the vehicle hypothetically would "move" from each of seven origin terminals to their destination terminal. The algorithm also ensures the driver complies with all of the HOS regulations.

***Schedule Algorithm*** **-** The schedule algorithm includes all the decision-making procedures within the choice algorithm. The schedule algorithm writes the selected origin-destination pair to the output table.

***Feasibility Algorithm*** **-** The feasibility algorithm screens out the 13 O-D pairs that would lead to the lowest utility, as well as eliminating all O-D pairs that are infeasible because of a driver's individual rest needs vis-à-vis his status in the HOS duty/rest cycle.

***Longer Restart Rest Period Algorithm*** **-** In actuality, many commercial truck drivers take longer restart periods than the minimum required by the 2003 HOS rule presumably in order to start their next working period in the morning or at a convenient or accustomed time. Therefore, the model reflects the longer restart rests by imposing a specific pattern of longer restart rests.

***Break Time Algorithm*** **-** In order to make the model more closely reflect the driving patterns of actual truck drivers, a break period of either 30 minutes or one hour is imposed whenever the CMV operator drives four straight hours with more than one hour left until the destination.

***Split Sleeper Berth*** **-** When the HOS option being considered allows, the model initiates the split sleeper berth algorithm whenever the CMV operator arrives at the pick-up or destination terminal and still has some time until the pick-up/delivery hour window.

## 3.3 SCENARIOS RUN

### 3.3.1 Long-haul and Regional Truckload, Random Schedule

Three basic scenarios were run with different lengths of haul:

- short-regional: minimum run: 120 miles, maximum run: 300 miles, average: 223 miles
- long-regional: minimum run: 260 miles, no maximum, average: 465 miles
- long-haul minimum run: 400 miles, no maximum, average: 708 miles

Minimum and maximum runs were imposed for the short-regional case. No maximum was imposed on the model for the long-regional and long-haul scenarios. A minimum was specified for these scenarios, and the difference in lengths of haul came from setting the long-regional and long-haul scenarios in different geographic territories.

The short and long-regional scenarios were set in the same geographic territory for the simulations run so far. This region is roughly the northeastern quadrant of the United States, starting with Illinois on the western end and extending to the East Coast through Indiana, Ohio, Pennsylvania, New Jersey and Delaware, plus New York and all of New England. The home terminal is in Cook County, Illinois. The long-haul scenario includes part of the Midwest—

Illinois, Indiana, and Ohio—and all the states west of the Mississippi. The home terminal is in Cook County, Illinois.  In terms of the default regional definitions set up in the model, the short- and long-regional scenarios included the Northeast and Midwest regions and the long-haul scenario included the Midwest and West regions.

As discussed in Section 1.2, four regulatory options were assessed.  Option 1 is the current HOS rule, allowing 11 hours of driving within a 14-hour tour of duty; allowing each 10-hour off-duty period to be split into two periods of at least 2 hours each, provided a sleeper berth is used and certain other requirements are met; and allowing drivers to re-start their 60- or 70-hour on-duty count after 34 hours of consecutive off-duty time.  We conducted simulations both allowing and disallowing sleeper berth splitting, and then took a weighted average of the results.  This approach allowed us to match results to actual driver behavior, which we have found to be split between drivers who use split their sleeper berth periods frequently and others who rarely or never do so.  Chapter 6 discusses how we weighted the results from each run.

Option 2 places strict limits on the splitting of off-duty time in sleeper berths.  We found that the advantages of splitting would arise only in very rare cases (in which 2 or 8 hours of sleeper berth rest makes an otherwise infeasible shipment a feasible shipment), and therefore excluded splitting from our analysis of Option 2.  This exclusion meant that the effects of Option 2 could be assessed by comparing the runs with and without allowing sleeper berth splitting which were conducted for Option 1.  (Additional runs were conducted for a more restrictive variant of Option 2 which allowed only 10 hours of driving within a 14-hour tour of duty.  This variant is discussed in Section 6.8.1.)

For Option 3 and 4, we were able to model precisely as the options are stated. Option 3 does not allow more than 10 hours of driving or the splitting of off-duty periods, and requires 58 hours off before restarting.  Option 4 does not allow more than 10 hours of driving or the splitting of off-duty periods, and requires 44 hours off before restarting.

For all four options, the model is simulated with the operating region limit of 100 miles and the simulation duration of 1 year.

### 3.3.2 Trucks Following Regular Schedules

Four scenarios were run with the four options discussed in the previous section.  The first and second scenarios were for trucks following daily schedules and the third and fourth scenarios were for trucks following weekly schedules.  In the first scenario, a truck works on weekdays and returns home at the end of each work day.  In the second scenario, a truck works on Saturdays in addition to weekdays and returns home at the end of each work day.  Similar to the first two scenarios, in the third scenario, the truck leaves home on Monday, picks up and delivers shipments on weekdays, and returns home on Friday evening to spend the weekend at home. The fourth scenario is very similar to the third scenario, but the operator returns home on Saturday and spends only Sunday at home.

The trips in the daily model have a minimum distance of 75 and maximum of 200 miles with the average of 154 miles.  The trips in the weekly model have a minimum distance of 120 miles and maximum of 400 miles with an average distance of 270 miles.

For these scheduled scenarios, the simulation model was adjusted so that there would not be any waiting time at the pick-up or destination terminals. It was also assumed that there would be only 30 minutes each of loading and unloading time, since the operators are following a predictable schedule, with coordination of the shippers, receivers, and carriers. These loading and unloading times may be shorter than generally seen, but were set to allow the model to generate realistic levels of use of the 11th hour of driving (which is usable only for drivers with relatively little loading, unloading, and waiting time in a 14-hour duty period). These scenarios were also run with the operating region limit of 100 miles and the simulation duration of 1 year.

# 4. COST OF CHANGES IN OPERATIONS

This chapter presents the approach to estimating the costs of the changes in productivity described in Chapter 3. The methodology used in estimating the costs in this study follow the same procedures used in the Regulatory Impact Analysis (RIA) conducted for the 2003 rule. As a result, this chapter first presents an overview of the methodology used in the 2003 RIA and summarizes the important cost estimates used in this analysis. This is followed by a discussion on the additional cost components expected to have a small impact on the total costs of the rule options.

## 4.1 COST COMPONENTS FROM PREVIOUS RIA

The analysis considered two main types of costs – employment costs for hiring new drivers due to the loss in productivity for the existing drivers and costs for purchasing new tractor-trailers and other support services for the new drivers. This section provides a summary of these costs. For more details about the methodology, refer to chapter 6 of the 2003 RIA.

### 4.1.1 Driver Labor Costs

A significant portion of the cost was estimated to be driver-related labor cost changes. Changes in the number of hours drivers can work or drive under the different HOS rule options were first translated to changes in driver's labor productivities using the simulation model explained elsewhere in this RIA. These changes were then used to calculate changes in the number of drivers needed over the baseline (we assumed 1.5 million drivers each in long- and short-hauls based on the industry profile presented in chapter 3 of the 2003 RIA).

Changes in the number of drivers were then translated into labor cost changes using the estimated wage-hours worked functional relationship for truck drivers. This functional relationship was estimated based on an ordinary least squares (OLS) regression model expressing truck driver wages as a function of various job attributes (e.g., hours worked per week, occupational experience, and their squared terms) and other worker characteristics (e.g., age, educational level attained, marital status, sex, etc). We used data from the Bureau of Labor Statistics Current Population Survey to estimate the wage equation for the non-union segment of the trucking industry. Refer to Exhibit 6-1 in the 2003 RIA for the estimated coefficients and other details about the regression results.

Based on the regression results, we estimated the predicted wages for truck drivers for different weekly work schedules and the average and marginal wage relationships as a function of hours worked. These relationships were then used to calculate both the additional wage costs (savings) for the *existing* drivers as they were allowed to drive more (fewer) hours under the different HOS rule options, as well as the incremental wage costs for the *new* drivers required under the different options (or cost savings if there was an increase in labor productivity under an option). The wages required for drivers under the different options were also determined by the elasticity of the market labor supply curve for all truck drivers. Based on an extensive review of the labor economics literature for blue collar workers, in general, and truck drivers, in particular, we estimated the elasticity of market labor supply curve to be 5 and used it in conjunction with the average and marginal wage curves to estimate the overall labor costs for the different rule options.

### 4.1.2 Other Non-driver Costs

Another part of the direct costs were related to the non-driver changes necessary as a result of the changes in the number of drivers. Several categories of non-driver costs were estimated. More details about these are provided in Sections 6.4 and 6.6 in the 2003 RIA:

- **Non-driver Labor –** Costs associated with overhead labor categories that are directly proportional to the number of drivers (e.g., driver managers, load planners, etc.) Thus, hiring more drivers for the 2003 HOS options implied there was a need to hire more overhead labor, leading to non-driver labor costs. We assumed companies spent an additional 4 percent of their total labor cost calculated above on these overhead labor categories.

- **Trucks –** Costs associated with purchasing tractors and trailers for the new drivers.

- **Parking –** Construction and maintenance costs for providing additional parking spaces at terminals.

- **Insurance –** Additional tractor-trailers represent increased capital stock with associated insurance costs (even if firm-level VMT is assumed to be constant).

- **Maintenance –** Additional tractor-trailers also require increased maintenance costs for regular safety inspections and other routine maintenance requirements.

- **Recruitment –** Costs associated with recruiting new drivers.

Using the driver labor and other non-driver cost components, the total cost of the FMCSA option (i.e., 2003 rule) for the long-haul was estimated to be a cost savings of a little over $1 billion for a 3.9 percent increase in driver labor productivity (2000$). See Exhibit 9-2 in the 2003 RIA for the breakdown of this total cost into the different components. This implied that a 1 percent change in labor productivity translated to approximately $275 million (2000$) in incremental *unit* costs.

For the present analysis, we updated this unit cost to 2004$ based on GDP deflator data from the Bureau of Economic Analysis' National Income and Product Accounts (NIPA), presented in Exhibit 4-1 below.

**Exhibit 4-1: GDP Deflator - (Base Year 2000=100)**

| Year | GDP Deflator |
|---|---|
| 2000 | 100 |
| 2001 | 102.40 |
| 2002 | 104.09 |
| 2003 | 106.00 |
| 2004 | 108.24 |

Source: BEA NIPA tables

Thus, a 1 percent change in labor productivity for truck drivers translated to $298 million (2004$) in incremental unit costs. Note that converting the total cost changes to a "unit cost" number, as is done here, is possible because our analysis showed that there was a linear relationship between changes in driver labor productivity and the associated costs.

Exhibit 4-2 below presents the breakdown of these unit costs into the different components discussed above (for the long-haul):

**Exhibit 4-2: Unit Costs for HOS Options**

| | |
|---|---|
| Change in Labor Demand | 1% |
| Change in Number of Drivers | 15,000 |
| **Driver Labor Cost** | **$176** |
| Avoided Labor Wages | -$429 |
| Avoided Labor Benefits | -$26 |
| New Labor Wages | $482 |
| New Labor Benefits | $149 |
| **Other Costs** | **$121** |
| Non-driver Labor | $7 |
| Trucks | $50 |
| Parking | $15 |
| Insurance | $11 |
| Maintenance | $19 |
| Recruitment | $20 |
| **Total** | **$298** |

## 4.2 ADDITIONAL COST COMPONENTS

### 4.2.1 Training Costs for HOS Options

Because several commenters for the 2005 HOS NPRM provided data on costs of re-training drivers and other personnel, we added this component to the other non-driver cost components discussed above. Using the total re-training costs provided by the commenters, we estimated a *cost per driver* based on the number of drivers for these companies. These "unit costs" varied between $75 and $150 per driver. The wide range is due to the variability in the level of detail provided by different companies. In particular, some companies did not make it clear whether the costs they estimated were only for driver re-training or if it included other non-driver staff re-training as well.

The lower end of the cost range was reported by a company (CR England) that appeared to have estimated only driver re-training costs. ICF decided that this may be too low if we consider re-training costs for both drivers and supporting staff. As a result, we decided to use $100 per driver as a reasonable point estimate for the re-training costs. Note that since these comments were for in response to the 2005 NPRM, we assume these costs to be in 2004$.

Using a 7-percent interest rate, 10 years as the amortization period, and 1.5 million total long-haul truck drivers (all standard assumptions used in the 2003 RIA), we calculated the annualized re-training costs for the long-haul segment to be $21 million (2004$). It should be noted here that while retraining costs may in fact vary somewhat by Alternative Option, the RIA for today's rule assumed these costs are constant. For example, under Option 2, while it might be the case that certain carriers would only retrain their long-haul drivers who currently use the sleeper berth provision, it may also be the case that some carriers would want to train their entire driver workforce (depending on how many drivers currently use the sleeper berth provision versus those who may use it in the future). As such, retraining costs for Option 2 could be considered conservative, in that they may over-represent the true retraining costs associated with this option.

### 4.2.2 Mode Shifts

As discussed above, restricting the hours truck drivers are allowed to drive (and work) reduces their productivity, thus requiring more drivers to maintain the same volume of business. Not only does this entail having to pay *all* drivers higher market wages to attract more drivers, this also means companies need additional equipment and non-driver labor. All this translates to higher costs for trucking companies and assuming a complete pass-through, implies higher rates for trucking as a result of the new options being considered. Consistent with the previous RIA, we assume that the probability of switching traffic from truck to rail is effectively zero for movements less than 250 miles. That is for hauls less than 250 miles, the demand for trucking is insensitive to changes in trucking rates.

However, for movements greater than 250 miles (considered to be the longest of the long hauls), we assume there is a non-trivial probability of mode shift due to the higher rates as these segments are more sensitive to price increases and are expected to lose some business due to a shift to rail.

In order to estimate the impact of mode shift on trucking volumes, we use results from the Logistics Cost Model (LCM) developed by Paul Roberts and used in the 2003 RIA. This model was exercised over a range of changes in truck prices from a 2.0 percent decrease to a 2.0 percent increase. Using the simulation results from these options we estimated a price elasticity of -1.4. This meant that, for a 1.0 percent change in trucking rates, there is a 1.4 percent change in trucking shipments, truck shipments increasing with a rate decrease and diminishing with a rate increase. This measure of elasticity was then used to estimate impacts on truck and rail traffic for each of the HOS rule options. Refer to Chapter 7 and Appendix D in the 2003 RIA for details about the model.

Exhibit 4-3 below summarizes the results of the mode shift effects for the FMCSA option in the 2003 RIA.

**Exhibit 4-3**
**Mode Shift Results**

| | **FMCSA** |
|---|---|
| Direct HOS-Induced Costs, LH Only | -1,073 |
| Percentage Change in Wages due to Driver Supply Elasticity | -0.3% |
| Change in LH Wage Bill due to Wage Increases | -206 |
| Total Change in LH Costs | -1,279 |
| Percentage Increase in LH Costs | -0.3% |
| Percentage Change in LH VMT due to Mode Shift | 0.25% |
| Change in LH Drivers due to Mode Shift | 3,820 |

Thus, a total cost savings of $1,279 million for the long-haul translated to a 0.3 percent increase in the total cost of all long-haul trucking. Using the appropriate cost adjustments for the long haul segments affected by mode shift, and a mode shift elasticity of -1.4, we estimated the percentage change in long-haul VMT due to mode shift to be 0.25 percent (for a 3.9 percent rise in labor productivity for the FMCSA option). Thus, a 1 percent change in labor productivity translates to a 0.064 percent change in VMT due to mode shift. Although this effect is small, we include it as a secondary effect when estimating the costs of the 2005 HOS rule options.

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# 5. ANALYSIS OF CHANGES IN CRASHES

## 5.1 INTRODUCTION AND PRIOR ANALYSIS

The safety effects of alternative changes from the long-standing HOS regulations in place prior to 2003 were analyzed in the 2003 RIA. The key features of the analysis approach are described in the following sections.

### 5.1.1 Literature Search and Model Selection

The analysis started with a comprehensive review of the literature relating to operator cognitive fatigue, effects of sleep deprivation and related issues. The review identified three main factors determining a truck drivers' ability to perform his or her task safely at any point during the work shift.

*Circadian cycle effects*. People experience a normal cycle in attentiveness and sleepiness through the 24-hour day. People having a conventional sleep pattern (sleeping for 7 or 8 hours overnight) experience maximum sleepiness in the early hours of the morning and a lesser low in the early afternoon. As well as reduced attentiveness during the low points of the cycle, people find it difficult to sleep soundly during high-attentiveness periods. The cycle is anchored in part by the natural sunlight and darkness cycle and in part by an individual's externally imposed pattern of sleep and waking times. It follows that the performance of night shift workers is always somewhat reduced, because of the influence of the natural day-night cycle on the circadian rhythm is not fully displaced by the night-work routine. In addition, circadian rhythms are persistent, and can only be shifted by 1 to 2 hours forward or backward per day by externally imposed changes in work/sleep routines and travel across time zones. Thus, changing the starting time of a work shift by more than these amounts, or the first night shift after a "weekend" break during which conventional sleep times were followed, will also reduce attentiveness.

*Sleep deprivation and cumulative fatigue effects.* Individuals who fail to have an adequate period of sleep (7-8 hours in 24 hours) or who have been awake longer than the conventional 16-17 hours will suffer sleep deprivation, leading to reduced performance. The deprivation accumulates with successive sleep-deprived days and is superimposed on circadian rhythm effects. Additional sleep deficits may be caused by breaking daily sleep into two shorter periods in place of a single unbroken period of sleep. Finally, unimpaired performance is not restored instantly after resuming a conventional sleep schedule, but may take two or three such sleep cycles to reach normal performance.

*Industrial or 'time-on-task" fatigue.* This is fatigue that accumulated during the working period, and affects performance at different times during the shift. Generally, performance declines with time-on-task, gradually during the first few hours and more steeply toward the end of a long period at work. Some studies also show reduced performance in the first hour of work as the individual makes the transition from off-duty activities.

### 5.1.2 Effects of Work and Sleep Schedules on Driver Performance

After reviewing multiple research studies on individual aspects of sleep and fatigue, and the limited number of efforts to integrate the available knowledge into an operator performance model for individuals performing repetitive cognitive tasks, a slightly modified version of the Walter Reed Sleep and Performance Model was selected for the analysis. The model does not include time-on-task effects, and the literature review failed to yield adequate quantitative information on performance in the last hour or two of a full-length 10 or 11 hour shift. Thus the analysis did not include 'time-on-task' effects.

The inputs to this model were representative truck driver schedules developed from a variety of industry surveys and similar sources. Separate schedules were developed for long and short-haul trucking and for multiple operating patterns within each of these broad categories. The metric used to quantify driver performance in the sleep model output was the response time score on the Psychomotor Vigilance Test (PVT), which has been widely used to measure behavioral alertness in a variety of settings. Past research and testing has established the relationships between the PVT scores and sleep histories to provide the core data that drives the model.

This risk model calculates PVT for each 15 minute period during which the operator is driving. These results are used to develop estimates of truck crash risk as described in Section 5.3.

### 5.1.3 Relationship Between Fatigue and Motor Carrier Crashes

The first step in the analysis is to develop a relationship between PVT values as calculated by the sleep and performance model and performance in the specific task of driving a truck. This was accomplished through a series of tests on a truck driving simulator with volunteer drivers who had been exposed to different sleep and waking routines. Output from the test program was used to develop a spreadsheet model to convert PVT scores into a crash risk increment relative to a fully rested driver. The individual 15-minute crash risk increments calculated from fatigue model outputs were then combined to obtain average crash risk increments for each overall schedule and a weighted average for all long and short-haul schedules.[29]

Finally, the crash risk increments derived from the fatigue model and simulator tests were calibrated against actual truck crash risk data to project the changes in crash risk based on alternative HOS requirements. The first step in this analysis was to estimate the fraction of crashes that appear to be attributable to fatigue. After reviewing the available data, the data from a Fatality Analysis Reporting System (FARS) maintained by the National Highway Traffic Safety Administration was found to be the most credible, although it obviously does not include data on crashes without fatalities but with injuries or property damage. The FARS database provides consistent data on the causes of crashes, while other highway crash databases (such as NHTSA's General Estimates System (GES) and the FMCSA Motor Carrier Management Information System (MCMIS)) contain only limited cause data. In particular, reporting practices varied by state, and data were often missing.

[29] Note that the most complete discussion of the analysis process, including the key step of establishing the relationships between driver schedules, the PVT score and crash risk are provided in Appendix G of the original report.

The FARS data was edited to eliminate records on individual crashes where key data were missing, and also where primary fault appeared to lie with other vehicles (not trucks) involved in the crash, and with certain hazardous weather conditions. The net result of this review was that the percentage of all truck-involved crashes where driver fatigue was a factor was 7.25%, taking an average of four years 1997-2000. In addition, there is evidence that a portion of crashes where inattention is cited as a cause were also due to fatigue. Twenty percent of inattention crashes (0.89% of all crashes) was added to the 7.25%, yielding a final estimate of 8.15% for fatigue-caused crashes. This percentage was projected to be reduced after implementation of the 2003 HOS regulations, to 7% for long-haul, and 3.5% for short-haul crashes[30].

### 5.1.4 Inexperienced Driver Effects

The 2003 RIA analysis concluded with a discussion of how the different HOS options outlined in the 2003 RIA would affect driver turnover and the need to recruit new and potentially inexperienced drivers into the industry. Research has shown that inexperienced drivers are at higher risk for a crash. The analysis concluded that there were differences in driver populations between the HOS scenarios, but that the differences were small. Because of the small differences and the likelihood that the adverse effects of bringing new drivers into the industry would be offset by slight reductions in VMT (due to mode shift), the inexperienced driver analysis was omitted from the current analysis.

## 5.2 Research Background on the Safety Effects

New information relevant to the effects of varying work/rest schedules and maximum driving time for truck drivers has become available in the period since completion of the 2003 analysis. This research has enabled refinements in the analysis of the safety effects of driving time and work/rest patterns. Most importantly, with this information, we have attempted to produce an estimate of the safety effects of varying maximum driving time between 10 and 11 hours. Incorporation of this analysis into the RIA is in response to concerns raised by the U.S. Court of Appeals in its dicta regarding maximum allowable daily driving time.

To provide a basis for the revised analyses, FMCSA initiated a supplementary search of the relevant literature. This search was supplemented by supporting analyses of data emerging from current research, including data from the Trucks Involved in Fatal Accidents (TIFA) database. Key points from the literature search as they relate to time-on-task effects, effects of short work/rest cycles, and driver performance/crash risk modeling are discussed below. Further details on the literature search are provided in Appendix (III).

### 5.2.1 Time-on-Task Effects

The analysis of time-on-task (TOT) effects in the safety analysis relied primarily on recent data from two ongoing research efforts, one by Ken Campbell of Oak Ridge National Laboratory, and one by a team led by Dr. Paul Jovanis at Pennsylvania State University. Both efforts are being

[30] Note that only about one-third of truck-involved crashes are the responsibility of the truck driver – the remainder are due to the actions of other vehicles involved, primarily private automobiles and light trucks. This means that fatigue is a significant factor in about 25% of all truck-involved crashes where the truck driver is responsible (or roughly 7 percent of the total).

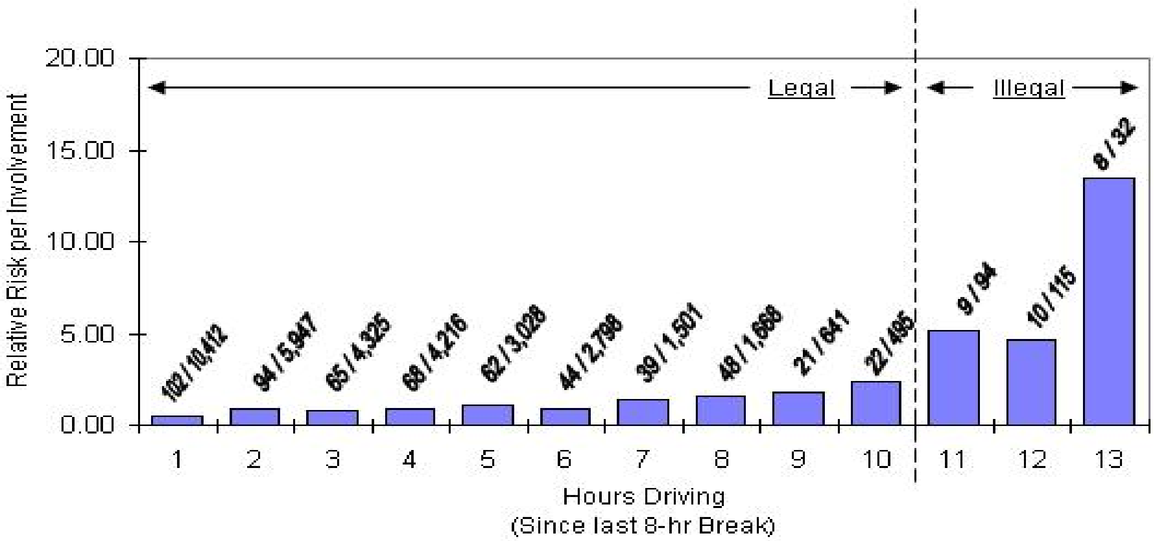
undertaken specifically for FMCSA, and both were ongoing at the time of this analysis, so this review relies on interim reports and other material provided to FMCSA (as identified in the footnotes) to date rather than formal final reports or published papers. As such, while the results of these studies are considered preliminary, they were thought to be the most appropriate of the limited data currently available to analyze TOT effects as part of this analysis. While recent, preliminary research findings by Hanowski [Hanowski, R.J., *et al*. (2005)] for FMCSA were also considered, the Hanowski work was not thought to be appropriate for this particular (TOT-related) analysis, since it limited its examination of commercial driver fatigue and performance to the 10$^{th}$ and 11$^{th}$ hours of driving. Despite the fact that the Campbell and Jovanis studies were still in progress at the time of this analysis, these studies do consider fatigue-related crash risk across the spectrum of driving hours (at least hours one through 11) and, given that research and data of this type are relatively limited, they were considered for the TOT analysis being conducted here.

The Campbell analysis[31] uses national level data from the TIFA database for the years 1991-2002, comprising over 50,000 truck-involved crashes. This database was developed from truck crashes in the NHTSA FARS database, with additional data on the driver and the carrier involved, complied by the University of Michigan Transportation Research Institute (UMTRI) after FARS data are published. Most importantly, UMTRI added data on time since the driver's last 8-hour break, the truck and carrier types, and the planned trip length to the FARS data to create the TIFA database. Note that, because this data collection effort predates the 2003 rule change, the results reflect pre-2003 HOS regulations: driving time was limited to 10 hours, the minimum rest time between trips was only 8 hours, and there were no provisions for a restart of the cumulative 7/8 day duty period. Also, the data do not include any information on the driver schedule over a longer period than the shift in which the crash took place. Thus, it is not possible to determine if cumulative fatigue may have been a factor.

The Campbell analysis addressed several aspects of the effect of driver fatigue on crash risk, including the fraction of crashes where fatigue was reported as the leading cause in FARS, the prevalence of fatigue by motor carrier industry segment, truck type, time of day, and hours of driving at the time of the crash. For the last of these analyses, a chart was provided of relative crash risk for each successive hour of driving. Relative crash risk for each hour is calculated as a multiple of the crash risk in the first hour. Exhibit 5-1 shows the results.

[31] Ken Campbell "Estimates of the Prevalence and Risk of Fatigue in Fatal Crashes Involving Medium/Heavy Trucks Update for 1991-2002 TIFA Files." Letter Report to FMCSA, February 25, 2005

**Exhibit 5-1**
**Relative Crash Risk by Driving Time Under the Pre-2003 HOS Rule**




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

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

For example, for the 10th hour of driving, Exhibit 5-1 indicates that the relative risk per involvement in a fatigue-related crash is roughly 2.5 times higher than in the first hour of driving (reading across to the vertical axis of the chart). In the 11th hour of driving, the relative risk per involvement in a fatigue-related crash is roughly five times higher than that in the first hour. The first number above each bar chart represents the number of large trucks involved in *fatigue-related fatal* crashes between 1991 and 2002 for each driving hour, while the second represents the total number of large trucks involved in *all fatal* crashes within that same driving hour. For example, within the 11th hour of driving, there were 9 large trucks involved in fatigue-related fatal crashes between 1991-2002, while there were 94 large trucks involved in all fatal crashes during that same driving hour. The figures above each chart help to provide a better understanding of the prevalence of large truck fatal crashes in each driving hour, in that they reveal that as driving hours increase, the number of fatal crashes, as well as fatigue-related fatal crashes, generally decrease in a steady fashion.

Using the 11th hour driving data as an example, the relative risk ratios representing each bar chart in Exhibit 5.1 were estimated via the following steps. First, the number of trucks involved in fatigue-related fatal crashes (9) within the 11th hour of driving were divided by the number of trucks involved in all fatal crashes in the 11th hour of driving (94). The result, 9.6 percent, represents the percentage of all trucks involved in fatal crashes during the 11th driving hour where it was determined that the truck driver was fatigued at the time of the crash. Second, the number of trucks involved in fatigue-related fatal crashes between 1991-2002 for *all* hours of driving (990) were divided by the number of trucks involved in all fatal crashes for all hours of driving (53,249), which yielded an overall ratio of 1.9 percent, or the percent of all large trucks involved in fatal crashes during this time period where the truck driver was determined to be fatigued at the time of the crash. Finally, to estimate the relative risk ratios that appear in Exhibit 5-1, the percent of all trucks where fatigue was present at the crash within each driving hour (i.e., 9.6 percent in the 11$^{th}$ driving hour) was divided by 1.9 percent, or the percent of all trucks involved in fatal crashes across all driving hours where it was determined that the truck driver was fatigued at the crash. The result is a relative risk estimate per involvement in a fatigue-related crash for each driving hour. In the case of the 11$^{th}$ driving hour, this estimate is equal to about five (or 9.6% divided by 1.9%), which is represented by the height of the bar chart in Exhibit 5-1 for the 11$^{th}$ driving hour.

There were some concerns with the TIFA data contained in Exhibit 5-1: first, there are very few crashes for drive times over 10 hours (i.e., only 9 fatigue-related crashes in the 11$^{th}$ hour, only 10 in the 12$^{th}$ hour, and only 8 in the 13$^{th}$ hour). Such limited populations of fatigue-related crashes raises uncertainty with regard to the relative risk ratios associated with the later driving hours, since the misclassification of a single crash as fatigue-related can affect the resulting relative risk ratios quite substantially. For instance, misclassification of a single fatal crash-involved large truck driver as fatigued in the 11$^{th}$ hour of driving would increase the number of trucks involved in fatigue-related crashes from 8 to 9, thereby increasing the relative risk ratio from 4.57 to 5.15, or 12.5 percent.

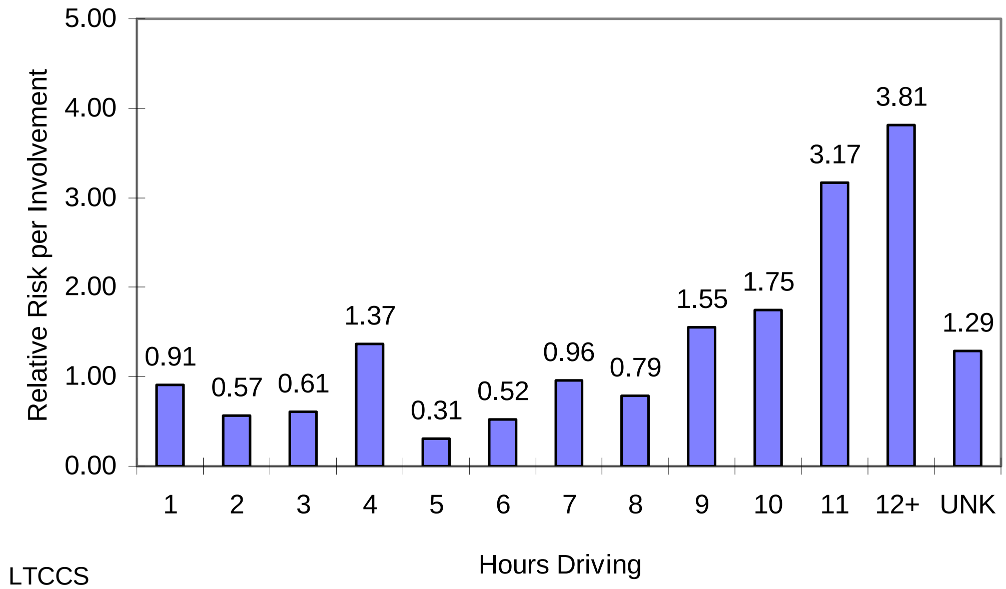
Other concerns with TIFA data include the fact that the pre-2003 regulations limited legal driving time to 10 hours, which meant that driving in the 11$^{th}$ hour was illegal at the time these data were collected. As a result, the data on the frequency of driving 11 hours or more could be underreported. As such, it is unclear whether fatigue-related crashes are over- or under-represented in the TIFA data set, since it is not possible to determine whether any under-reporting involved all fatal crashes during the 11$^{th}$ hour of driving, or just those where the truck driver was determined to be fatigued. Also, because driving beyond 10 hours was illegal under the pre-2003 rule (or at the time these data were collected), the relative risk of the subpopulation of commercial drivers admitting to illegal driving during the 11$^{th}$ hour or later may not reflect the relative risk of drivers operating legally under the 2003 rule. Unfortunately, TIFA data for calendar year 2004 (the first year when driving in the 11$^{th}$ hour was permissible) will not be available until late 2006. Given these uncertainties, FMCSA conducted a sensitivity analysis regarding the estimates used in the RIA for the relative risk of a fatigue-related crash. The results of this and other sensitivity analyses can be found in Chapter 6, Section 8, of this RIA.

Campbell followed this analysis with a similar analysis of preliminary data (as of December 2004) from the Large Truck Crash Causation Study (LTCCS)[32]. These data covered the period April 1, 2001 to December 31, 2003 and contains a sample of approximately 1,000 crashes. The result of the driving time analysis is shown in Exhibit 5-2. The overall result is similar to that derived from the TIFA data, although relative fatigue involvement factors for hours exceeding 10 hours represented by the LTCCS data appear to be lower than from TIFA data. The preliminary LTCCS data include injury crashes as well as fatal crashes, and it is not clear whether or not the

[32] Ken Campbell "Comparing GES and LTCCS Preliminary (December 22) LTCCS File," Letter Report to FMCSA, March 11, 2005.

relative risk data includes the injury crashes. However, it is important to note that the LTCCS data are still preliminary and have not yet been published in final form.

**Exhibit 5-2**
**Relative Crash Risk by Driving Time (Campbell – LTCCS Data)**




In contrast to the Oak Ridge/Campbell analysis, the Penn State/Jovanis analysis relies on a sample of data obtained from three cooperating LTL carriers, as described in two interim reports to FMCSA[33],[34] Currently, the sample includes seven-day driver records for 231 crashes and comparable data for 462 similar periods without a crash. The sample periods were randomly selected. All the data obtained to date are for the calendar year 2004 after the introduction of the revised HOS regulations which permitted an 11th driving hour and required longer breaks between onduty periods. Conversely, the sample of commercial operators driving in the 11th hour is very small, with the data limited to 34 drivers. TOT task effects were calculated for the entire sample and for different subsets of the data, including operations with team drivers and sleeper berths, and different start times and shift patterns.

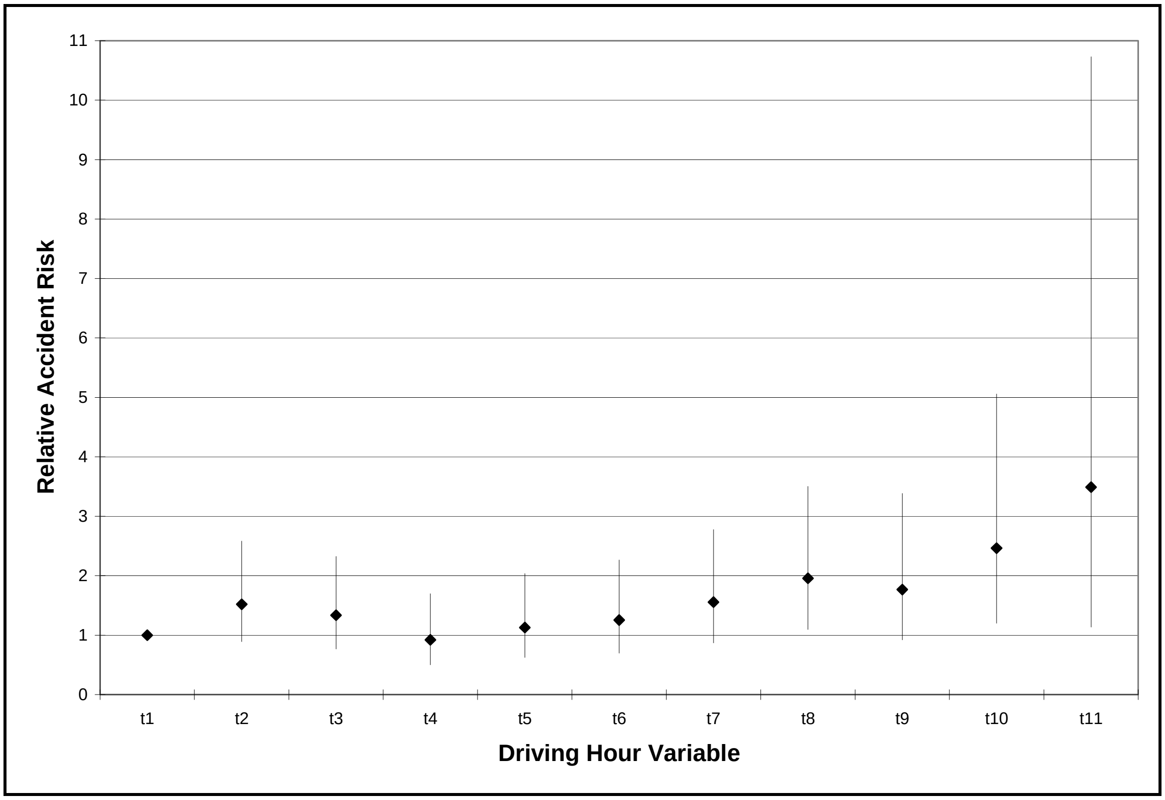
The primary result for all industry segments and driving routines combined is shown in Exhibit 5-3. The main limitation with this analysis is that it is representative of only one trucking industry segment (LTL carriers). Additionally, there are very few driver cases involving 11 hours of driving (34, which includes both crash and non-crash cases) are rather low, which is presumably causing the very high variance surrounding the estimated 11th hour crash risk. The data show an 11th hour risk factor of about 3.4, which would be substantially higher than the equivalent estimates derived from the Campbell - LTCCS data discussed above. Jovanis also

[33] Paul P. Jovannis, Sang-Woo Park, Ko-Yu Chen, "Crash Risk and Hours Driving: Interim Report" Letter report to FMCSA, Pennsylvania Transportation Institute, Penn State University, February 25, 2005

[34] Paul P. Jovannis, Sang-Woo Park, Ko-Yu Chen, "Crash Risk and Hours Driving: Interim Report II" Letter report to FMCSA, Pennsylvania Transportation Institute, Penn State University, April 15, 2005.

reports that the results are comparable to results obtained from a similar analysis of data gathered in the 1980s.

**Exhibit 5-3**
**Relative Crash Risk with Driving Time**
**(Jovanis Sample of LTL Operation)**




### 5.2.2 Driver Performance and Crash Risk Modeling

An evaluation of available models to calculate performance as a function of sleep and work schedules was carried out in preparation for the 2003 RIA analysis. At the time, the Sleep Performance Model (SPM) developed by the Walter Reed Army Institute of Research (USAIR) was selected as the most appropriate for this analysis. Appendix E of the 2003 RIA describes two other candidate models that were not selected. Since that time, the SPM was further refined and expanded in a cooperative effort involving multiple research organizations. The model has been adapted and applied to a number of different activities, including military operations and surface and air transportation modes. Several considerations prompted selection of the revised model for this RIA analysis:

- Use of a related model should ensure reasonable consistency with the 2003 RIA.
- A limited literature search conducted for this analysis failed to identify any comprehensive model that would be a credible candidate for this analysis, and which had not been previously evaluated.

- The model had already been adapted and used for performance analysis for different transportation operations.

- The model had been incorporated into a commercially-available software package complete with user interfaces, facilitating use of the model.

Details of the model's approach to analyzing the effects of driving schedules on driver performance is documented in a paper by Steven Hursh and his colleagues at the WRAIR, the Naval Health Research Center (NHRC) and the Air Force Research Laboratory (AFRL).[35] After moving to SAIC, Hursh developed a commercial software tool that applies the analysis methodology (called the Sleep, Activity, Fatigue, and Task Effectiveness (SAFTE) model) to a Fatigue Avoidance Scheduling Tool (FAST). The tool is closely related to the WRAIR SPM used in the 2003 RIA, and is continually being developed and refined as new research data has become available from WRAIR, NHRC and AFRL research programs. Further refinements to the tools were sponsored by AFRL and the US Department of Transportation in air and surface transportation activities. ICF applied the current commercially available version of the FAST/SAFTE tool to this analysis of variations in HOS regulations.

The core concept behind the SAFTE model is that of a sleep reservoir which individuals draw upon while awake and replenish by sleep. The overall structure of the SAFTE model is described below.

Alertness or performance is a function of three inputs:

- The amount of depletion of the sleep reservoir – research shows performance declines to the low level of 25% of that of a fully rested individual after 72 hours continuous wakefulness. A linear relationship between performance and sleep debt is used, although some research results suggest a non-linear relationship. Both the slope and shape of relationship can vary with the test task used to assess performance.

- Sleep inertia effects. Full wakefulness is not attained instantly on awaking. Instead there is a period, typically on the order of 1 to 2 hours, depending on sleep intensity and the current status of the sleep reservoir, during which performance recovers to a peak value, after which the normal decline with reservoir depletion resumes.

- Circadian rhythm effects. As discussed in Section 5.1.1, circadian cycles affect alertness as a function of time of day and the individual's sleep/waking cycles over the past several days.

The model applies the results of numerous research studies of each effect to provide a continuous estimate of performance levels over time. In principal, the model is not limited to one specific performance measure (such as the Psychomotor Vigilance Test (PVT) measure used in both this and the original truck HOS analysis), provided there is a sufficient research base to establish the relationships between task performance and the status of the sleep reservoir.

[35] Steven R Hursh, Daniel P. Redmond, Michael L. Johnson, David R. Thorne, Gregory Belenky, Thomas L. Balkin, William F. Storm, James C. Miller and Douglas R. Eddy "Fatigue Models for Applied Research in Warfighting", Aviation Space and Environmental Medicine, Vol 75, Number 3 Supplement, 2004.

Replenishment of the sleep reservoir also depends on multiple inputs, as follows:

- Length of sleep. A non-linear function exists between the length of sleep and the amount of replenishment. The per-hour replenishment is less for the first three hours of sleep than later in the sleep cycle. The model also incorporates a factor for fragmented sleep, to quantify the reduction in sleep effectiveness due to frequent wakening, such as from external noise and vibration or a sleep disorder.

- Reservoir depletion level. Generally the lower the sleep reservoir, the greater the restorative effect of sleep. The term sleep intensity is used to quantify this effect.

- Circadian rhythm. Sleep is more effective (higher sleep intensity) around the low points in the circadian rhythm.

As with performance estimates, the SAFTE model applies the results of numerous research studies to estimate reservoir replenishment for a given period of sleep.

The authors conclude by identifying a number of areas where there are unexplained contradictions or anomalies in the available data, and where further research would be useful. One key area is the relationship between the performance metric and the actual demands of a specific task. In the HOS analyses, a relationship was developed between PVT and crash risk from truck driving simulator tests. Similar relationships are needed for other tasks, both to identify the most appropriate measure for a specific task and to establish a relationship for use in practical applications of the model.

The procedures for estimating the crash increment as a function of average PVT values and then the variation in estimated fatal and non-fatal truck involved crashes due to driver fatigue effects are unchanged from the 2003 RIA analysis, except that a baseline estimated performance under the 2003 regulations is substituted for the baseline before the 2003 change.

### 5.2.3 Other Relevant Literature

A broader review of literature, concentrating primarily on material identified since the 2003 RIA is provided in Appendix (III). Some specific research findings of relevance to this analysis included the following:

- A detailed laboratory study by Balkin et al.[36] at the WRAIR, sponsored by FMCSA and other transportation interests, in which a sample of truck drivers with different levels of sleep deprivation operated a truck driving simulator, and were evaluated by the number of crashes during simulated driving and using the PVT. An associated field study used wrist actigraphy to determine sleep times and duration for a sample of long and short haul truck drivers. This study provided the key link between PVT as calculated by the FAST/SAFTE model and truck crash risk, used in this analysis (see Section 5.4.4) and also some material to support the analysis of off-duty activities as described in Section 5.4.1.

[36] Balkin, T, Thome, D., Sing, H., Thomas, M., Redmond, D., Wesenstein, N., Williams, J., Hall, S., and Belenky, G. "Effects of sleep Schedules on Commercial Motor Vehicle Driver Performance" FMCSA Report 2004.

- A field study to compare driving performance and sleep patterns of team and single drivers on long, multi-day trips, sponsored by FMCSA.[37] The most interesting result from this study was that team drivers suffered fewer instances of extreme drowsiness than single drivers, in spite of short and less effective sleep periods in the truck's sleeper berth, while the truck continued traveling with the second driver. Team drivers tended to drive more conservatively that single drivers and would manage fatigue by swapping drivers when the active driver was fatigued. Single drivers tended to push on in spite of fatigue, exposing themselves to greater crash risk. This result can be contrasted with the results from the FAST/SAFTE model that showed team drivers to have a lower performance than a single driver (Section 5.4.1), primarily because the first part of a period of sleep is less effective at replenishing the sleep reservoir than the later part. At least in the observed population, the basic performance disadvantage of a typical team driving schedule was more than offset by an effective fatigue management strategy employed by the drivers . The small sample size (56 drivers, including 26 team drivers), however, and the possibility that the drivers were self-selected and therefore not necessarily representative, means that we may not be able to generalize the study's results.

- In another FMCSA-sponsored study[38], Hanowski et.al. investigated the relationships between fatigue and critical incidents, and between sleep history and fatigue for a sample of short-haul truck drivers. Key findings from the study included the following:

    - There was clear evidence of fatigue (eyelid closure) in 21% of at-fault critical incidents
    - Much variation in on-the-job sleepiness was related to off-duty sleep behavior rather than anything related to the job.
    - Critical incidents were concentrated at the beginning of the week.

- A recently published (2004) survey of truck drivers concentrating on the effects of safety management practices by the trucking firm on crashes and close calls.[39] The study was unable to establish any relationship with crashes (possibly because fewer than 10% of truck crashes are due to fatigue), but showed that good safety management had a significant effect on close calls. Good practices included regular scheduling and careful management of fatiguing loading and unloading activities. The study also observed that some drivers started work fatigued, and that employers could implement policies to encourage sensible off-duty fatigue management in their employees.

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[37] Dingus T., Neale, V., Garness, S., Hanowski., R., Keisler, A., Lee, S., Perez, M. and Robinson, J. A. "Impact of Sleeper Berth Usage on Driver Fatigue" Final Report, FCMSA-RT-02-070, 2002.

[38] Hanowski, R. J., Weirwille, W. W., Gellatly, A. W., Early, N., and Dingus, T. A. 'Impact of Local Short-Haul Operations on Driver Fatigue" FMCSA Report 2000.

[39] Morrow, P. C., and Crum, M. R. "Antecedents of Fatigue, Close Calls and Crashes Among Commercial Motor Vehicle Drivers" Journal of Safety Research, Vol 35, Number 1, 2004.

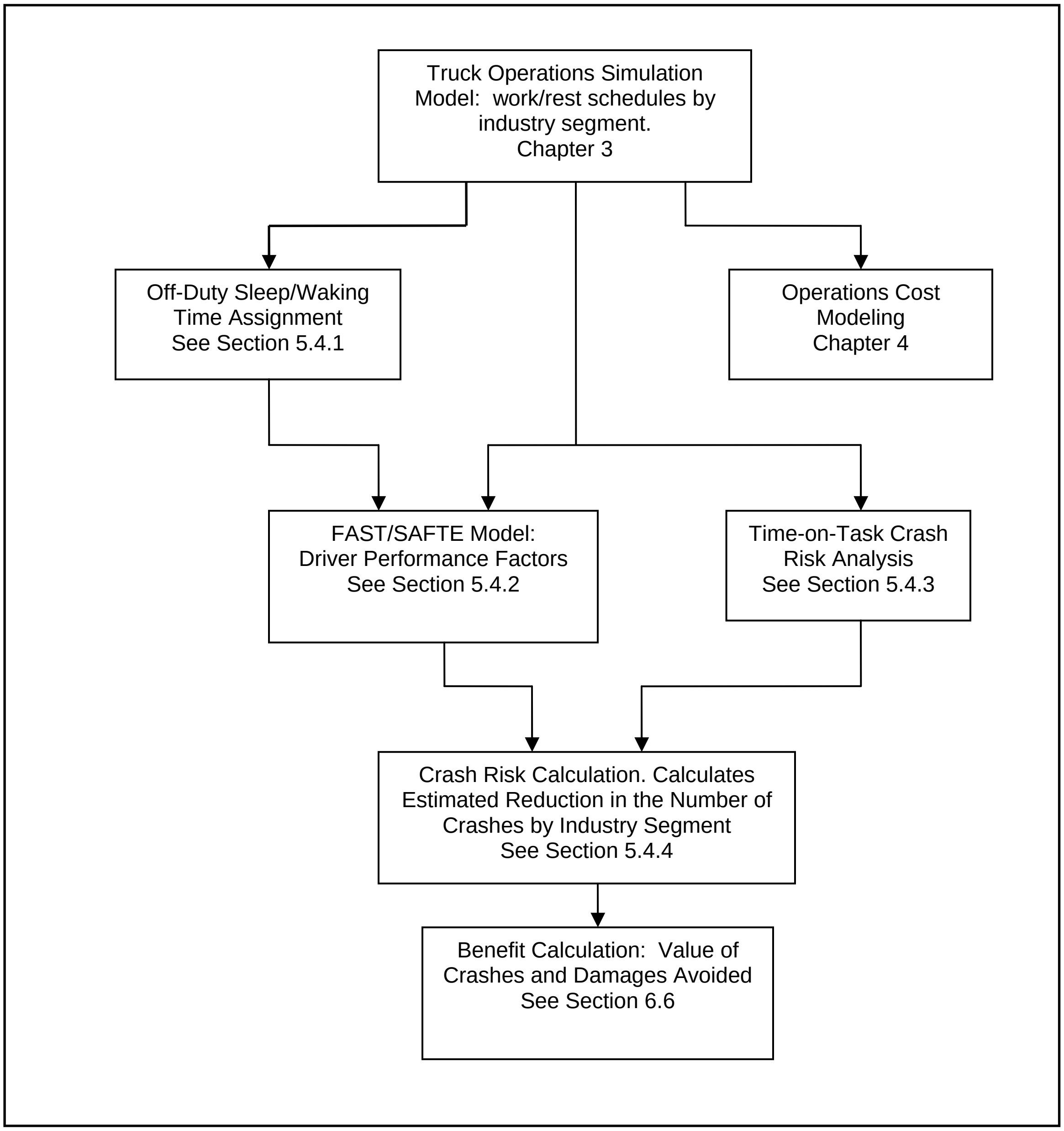
## 5.3 OVERVIEW OF CRASH AND BENEFIT ANALYSIS

In this analysis, the base case is the set of HOS regulations implemented in 2003, and the analysis evaluates the effects of changes from these regulations. Revisions to the 2003 RIA analysis include inclusion of TOT effects and use of the newer FAST/SAFTE model for analysis of driver performance as a function of work and rest schedules.

The overall approach to this analysis is illustrated in the flow diagram, Exhibit 5-4. The crash and benefit analyses use the output of the truck operations simulations as the starting point for the analysis. The operations analyses, described in Chapter 3, provide a series of realistic truck driver schedules for each trucking industry segment, and for each set of HOS regulations being examined in this analysis. The schedules specify driver activity for each half hour (off duty, on-duty driving, and on-duty performing other activities such as loading, unloading, and waiting) over a multi-day period. The outputs of the simulations are used as inputs into cost modeling described in Chapter 4, as well as the crash analysis described in this Chapter.

The one piece of data about driver schedules that the simulation model does not provide is how the driver splits off-duty time between sleep and other personal activities. This information is an essential input to the driver performance model described in Section 5.4.1 A separate analysis to address this question was carried out to add this information to the working schedules, based on sleep pattern surveys and similar research. These analyses led to a set of algorithms for sleep time based on the length of the break and the time of day at the start and end of the break.

**Exhibit 5-4**
**Flow Diagram for Crash Risk Reduction and Benefit Calculations**




The driver performance analysis is described in Section 5.4.2. The FAST/SAFTE human performance model, developed in part from research led by the Walter Reed Army Institute of Research, was used for the analysis. The inputs to the model were the driver schedules developed in truck operations simulations described in Chapter 3, supplemented by the analysis of driver off-duty hours described in Section 5.4.1. The model applies a large body of sleep and fatigue research, including circadian rhythms to provide an operator effectiveness percentage relative to a fully rested individual.

Because, as discussed, the FAST/SAFTE model does not take into account TOT effects, a separate analysis of these effects was performed to determine the relationship between TOT and crash risk. This relationship was applied to the driver schedules from the simulation model to estimate the effects of changing the maximum driving time from 11 hours to 10 hours.

## 5.4 DETAILED DESCRIPTION OF THE REVISED CRASH AND BENEFIT ANALYSIS

### 5.4.1 Off-duty Sleep Time Assignment

In order to use the FAST/SAFTE model to process the outputs of the operational model, we needed to determine how much sleep the drivers were getting and when that sleep would occur during a given off-duty period. This procedure is described below.

In the productivity analysis outlined in Chapter 3, we were concerned with the length of the driver's on-duty, off-duty, and driving periods. While the safety model requires the length of the on-duty and off-duty periods, it also requires the amount of sleep taken by the driver, and the placement of that sleep within the off-duty period. These are the two functions of the sleep allocation model. Once the driver's schedule has been separated into on-duty periods, off-duty periods and sleep periods, it is ready for input into the FAST/SAFTE model.

The first step in the sleep allocation process is to determine how much sleep a driver is expected to get based on past work history. This calculation is a decreasing function based on the cumulative amount of on-duty time in the previous 24 hour period. The basic function is identical to the one used in the 2003 RIA. For a driver who works 14 hours a day on a continuous basis, that amounts to 6.57 hours of sleep per 24 hour period. Once the amount of sleep is determined, the model checks to see how much sleep the driver has received over the previous 24 hour period. If the driver has had more sleep than he is expected to get, a sleep surplus is assumed to exist. If the driver requires more sleep than he has received over the last 24 hours, he has a sleep deficit and the model allocates sleep until the driver's deficit has been reduced to zero or until the driver begins his next on-duty period, whichever comes first.

The second step in this process is the actual placement of the sleep within the off-duty period. To begin, the model consolidates all of the driver's sleep within a period of time. For off-duty periods less than 24 hours, it is assumed that the driver will rest in a single session, and so the sleep is consolidated into a single sleep period. For rest periods equal to or longer than 34 hours, the driver is assumed to be taking a week-end break or restart of some length, and multiple sleep periods will be allocated based on the length of the rest period. Once the sleep has been consolidated, it needs to be placed within the off-duty period. After some test runs involving different rest period lengths and times of day, we assumed that the driver's sleep period should be placed as late in his off-duty period as possible, while still allowing him to wake up 30 minutes prior to the beginning of his next on-duty period. This 30-minute buffer was included to allow the driver to overcome any sleep inertia present when he awoke. We determined that by placing the driver's sleep towards the end of his off-duty period, it allowed him to start his on-duty period with the highest possible level of effectiveness. Whether drivers base their personal sleep allocation decisions on this same rationality is not clear at this time.

### 5.4.2 Modeled Impacts of Individual Schedule Factors on Performance

This section presents the results of investigations of several individual aspects of driver schedules using the FAST/SAFTE model. These investigations cover the effects of lengthening the breaks between multi-day work periods, changing the degree of regularity in schedules, and splitting rest periods into two pieces.

**Impact on Driver Effectiveness of Longer Weekly Breaks**

One important observation made while using the FAST/SAFTE model was the relatively small improvement in driver effectiveness when shifting from the 34-hour restart to a 58-hour restart. To compare these scenarios, we modeled two drivers on regular schedules and compared their levels of effectiveness. Both drivers had on-duty periods of 14 hours from 7 AM to 9 PM. Off-duty periods of 10 hours made up the remaining portion of the day, from 9 PM to 7 AM the following day. Those drivers with a 34-hour restart worked 6 consecutive days with 1 day off and those drivers with a 58-hour restart worked 6 consecutive days with 2 days off. Because the function used to estimate sleep for drivers is sensitive to differences in time off, the extra day off in the second scenario leads to about 1.6 extra hours of sleep, once per week. Thus, the driver with more time off can be expected to start the work week slightly more rested, and therefore with a lower crash risk. The average driver effectiveness results for the 14-hour on-duty periods are summarized in Exhibit 5-6 below.

**Exhibit 5-6**
**Average Effectiveness during On-Duty Periods**

| 34-Hour Restart | | 58 Hour-Restart | |
|---|---|---|---|
| Average Effectiveness | 94.10% | Average Effectiveness | 94.59% |
| St. Dev. | 1.69 | St. Dev. | 1.69 |
| Minimum Effectiveness | 90.51% | Minimum Effectiveness | 90.84% |

Thus, an extra day off, and the slight increase in sleep it makes possible, does show an increase in average effectiveness. The change is quite small, however; less than half of one percent, which would translate into a reduction of only a quarter of one percent in crashes. The safety model results based on the outputs from the productivity model described in Chapter 3 generally support this conclusion, as shown in Chapter 6.

**Importance of Regularity in Driver Schedules**

Another observation from the results of the safety modeling was the importance of maintaining a ‘regular’ schedule. By ‘regular’, we are referring to the driver’s ability to work and rest in the same general timeframe over consecutive work days. The importance of regularity stems from the effect that circadian rhythm has on driver effectiveness. Those drivers that had substantial shifts in their daily work/rest cycle performed considerably worse than those drivers that maintained a relatively constant schedule. It should also be noted that those drivers that shift to an entirely new schedule and maintain it over a period of weeks will eventually adapt to the new circadian rhythm. It is those drivers that shift to a different schedule on a daily or weekly basis that show substantial drops in effectiveness. As a visual example, compare the two FAST model screen shots below.

**Exhibit 5-7**
**Driver on a 'Regular' Schedule**

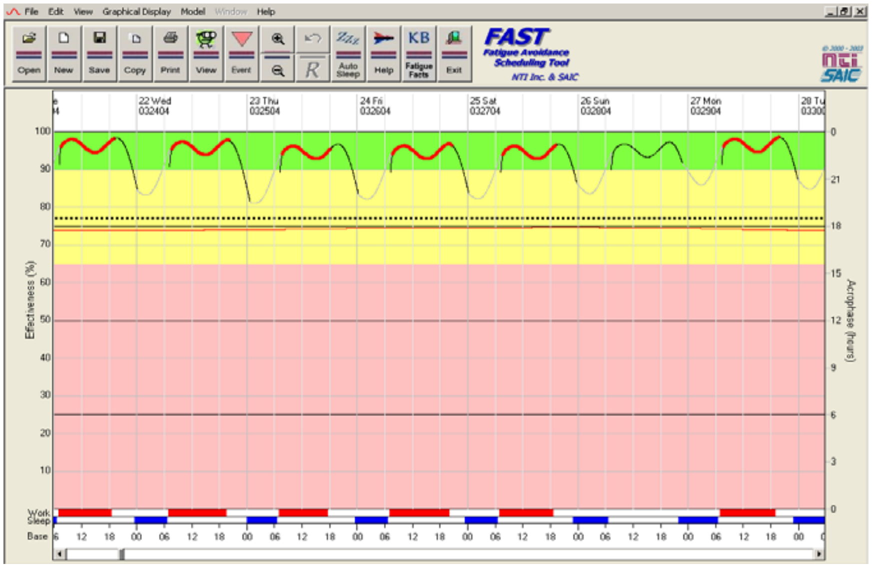
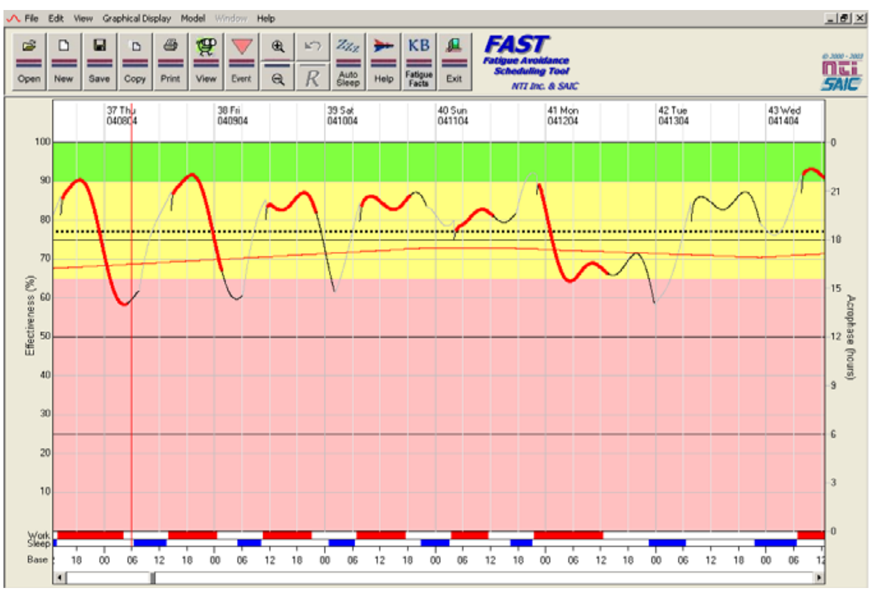



Exhibit 5-8
**Driver on a 'Variable' Schedule**




The 'regular' driver, in addition to showing a higher overall effectiveness, also shows much less variability in effectiveness. The large drops in effectiveness shown in the output of the variable-schedule driver are a characteristic of a constantly changing schedule. In the two examples above, the average driver effectiveness over a one-year period for the 'regular' schedule driver was 92.95%. This compares very favorably to an average effectiveness of 77.89% for the driver with the variable schedule.

**Driver Effectiveness – Split v. Continuous Sleeper Berth Periods**

Another important observation from the FAST/SAFTE model was the difference in driver effectiveness values based on how drivers took their off-duty periods, and specifically their sleep periods. Of particular interest were drivers who split their sleep period as compared to those that chose not to split. To model these two different drivers, we used the FAST/SAFTE model to calculate the effectiveness of drivers that had 10 hours of on-duty time and 14 hours of off-duty time each day. One driver was given the 14 hour off-duty period in one single block and the other driver was given two 7 hour off-duty blocks. Twelve simulations were run for each driver, each offset by 2 hours, to determine the combined effect of splitting and circadian rhythms. Four weeks of driver data were modeled for this particular analysis. In general, drivers who split their sleep period into two, 7-hour blocks had lower levels of effectiveness than those drivers that took one continuous 14-hour break. Two screen shots from the FAST/SAFTE model show the difference in effectiveness for a driver that chooses not to split and one that does split their off-duty period.

**Exhibit 5-9**
**Driver with Continuous Off-duty Periods**

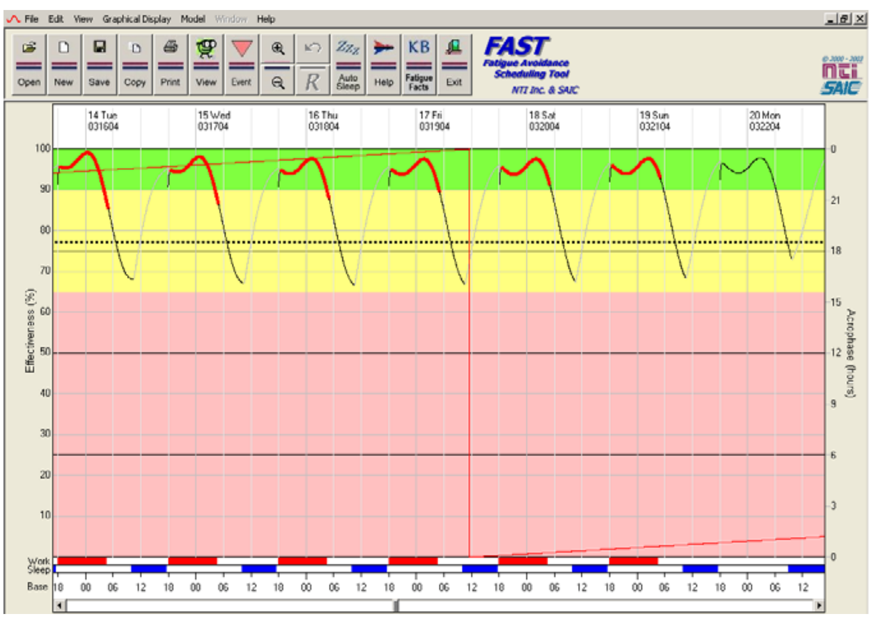
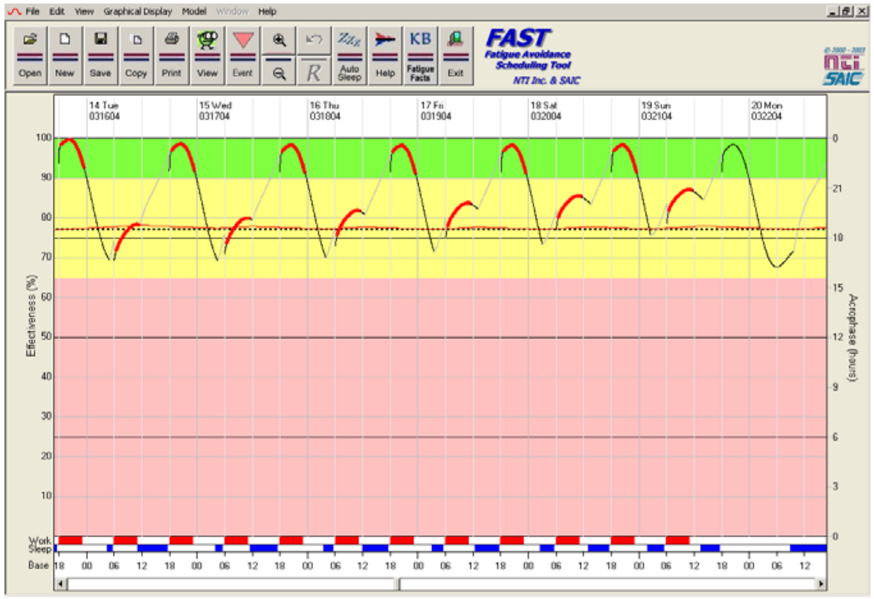
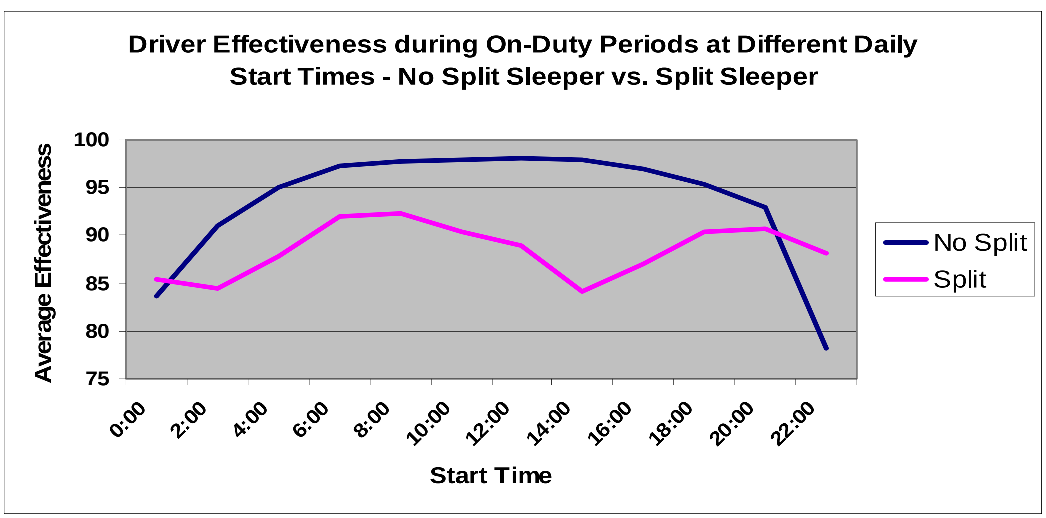


**Exhibit 5-10**
**Driver with Split Off-duty Periods**




At different start times over the course of a 24-hour period, the driver that chooses not to split generally has a higher average effectiveness than the driver that splits. However, our modeling shows that drivers beginning their shift between the hours of 22:00 and 0:00 show higher levels of effectiveness if they choose to split their rest period. Exhibit 5-11 summarizes our findings.

**Exhibit 5-11**
**Driver Effectiveness at Different Start Times – With and Without Splitting**

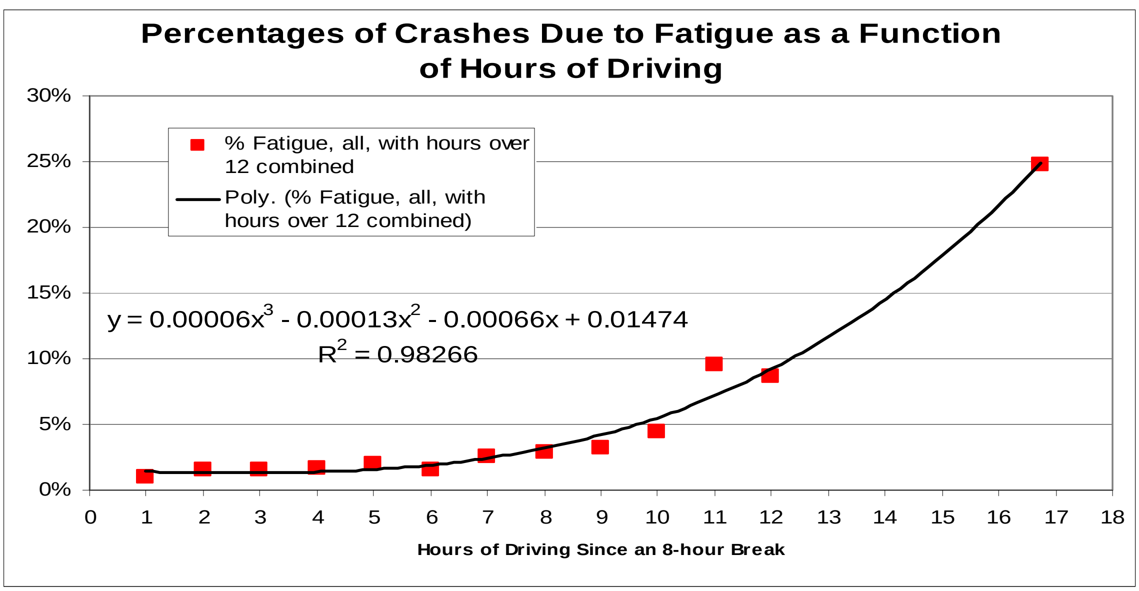



### 5.4.3. TOT Analysis

The TOT analysis relies on crash risks by hours driving, derived from Ken Campbell's analysis of Trucks in Fatal Accidents (TIFA) data as described in Section 5.2.1. Exhibit 5-12 takes the fatigue-related crash risk by driving hour from Ken Campbell's research and fits a cubic curve to the data. Note that that the fitted curve suggests that the particularly high risk factor observed by Campbell for the 11th hour may be an outlier. Relative risk data for the 13th driving hour and beyond were combined due to the very small number of crashes that occurred in each of these hours (i.e., in some hours, there were no fatigue-related crashes recorded).

Campbell's data express relative risk as a multiplier of the first hour risk. This has been converted into actual percentage crash risk. As noted earlier in Section 5.2.1 of this chapter, the TIFA data compiled by Campbell have several limitations, including: (1) the number of fatigue-related crashes in the 11th hour and beyond is very small; (2) because driving beyond 10 hours was illegal under the pre-2003 rule, the relative risk of the subpopulation of commercial drivers admitting to illegal driving during the 11th hour may not reflect the relative risk of drivers operating legally under the new rule; and (3) because the required off-duty period pre-2003 was only 8 hours long, and not the longer 10-hour period off duty currently required, the data reflects drivers who may well have been more fatigued at any given time on task than drivers would have been if the data had been collected under the 2003 rule. Limitations (2) and (3), all other things equal, argue that the Campbell data may over-estimate the true risk of driving during the 11th hour in the current state of the world. Limitation (1) argues that any result from the Campbell data carries with it a considerable amount of uncertainty. Because of this uncertainty, Section 6 presents a sensitivity analysis to test the robustness of the conclusions of the impact analysis.

**Exhibit 5-12**
**Crash Risk as a Function of Hours of Driving**




The curve in Exhibit 5-12 shows that fatigue-related crash risk starts rising after the six or seven hours. Therefore, for the eighth hour and beyond crash risk was increased by a factor equal to the ratio between the estimate for each hour represented by the polynomial and the average fatigue crash risk. These factors were applied in the procedure for estimating crash risk from the performance data provided by the FAST/SAFTE tool, as described in Section 5.4.4, below.

### 5.4.4. Crash Risk Analysis

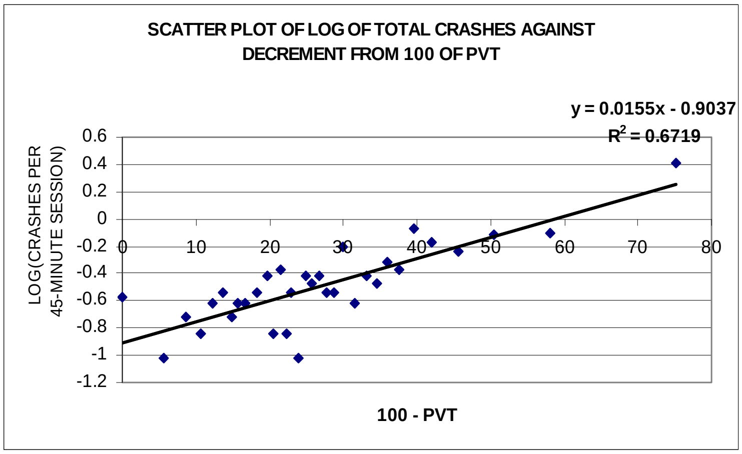
This section explains how the FAST/SAFTE tool outputs and the relationship between crash risk and TOT are combined to provide an estimate of crash risk for each HOS option. The steps in the analysis are as follows:

- Estimate raw crash risk increment from FAST/SAFTE performance data for each schedule
- Apply the TOT adjustments to all schedules that exceed 7 hours driving time in one shift.
- Weight and average crash risk increment values for individual schedules (after applying the TOT adjustment), to obtain crash risk increments for each trucking industry segment and for the industry overall.
- Adjust and scale the raw crash risk increments so that industry-wide crash risk attributable to fatigue matches the projected real-world fatigue-related crash risk in the baseline (Option 1).

This procedure is identical to that used in the 2003 HOS RIA, except for the addition of the TOT adjustment to crash risk estimates. The following paragraphs summarize the analysis steps. Further details can be found in Appendix G of the 2003 RIA.

**Estimate raw crash increment.** The primary source of data to form a link between crash risk and PVT scores produced by the FAST/SAFTE tool was a laboratory study carried out by Walter Reed Army Institute of Research, in which driving performance on a truck simulator was compared with PVT measurements for different levels of sleep deprivation (see Section 5.2.3). A robust straight line relationship between the log of crashes during a 45 minute driving session and fatigue level as measured by 100-PVT score was obtained. Exhibit 5-13 shows the scatter plot and the linear relationship. PVT scores were scaled so that a score of 100 indicates a fully rested individual.

**Exhibit 5-13**
**Relationship of PVT to Relative Crash Risks**




**TOT Adjustment.** Based on the discussion in Sections 5.2.1 and 5.4.3, a driving time risk factor was applied to all schedules over 7 hours. The table, Exhibit 5-14, lists the increase factor for average crash risk for drive times of 8 or more hours, calculated from the polynomial shown in Exhibit 5-12.

**Exhibit 5-14**
**TOT Crash Risk Multipliers**

| Driving Time in One Tour of Duty | Risk Increase Relative to Average Driving Hours |
|---|---|
| 8 | 1.09 |
| 8.5 | 1.26 |
| 9 | 1.44 |
| 9.5 | 1.65 |
| 10 | 1.89 |
| 10.5 | 2.16 |
| 11 | 2.46 |

Source: Exhibit 5-12 and ICF calculations

These factors were applied to each crash risk increment calculated by the FAST/SAFTE model.

**Calculate Raw Crash Risk Increments by Industry Segment.** The crash risk increments as calculated by the FAST/SAFTE model, with TOT adjustment for shifts of 8 hours and over, were averaged for each truck industry segment and for the industry overall.

**Estimate Actual Fatigue-Related Crash Risk**. The final stem in the analysis is to convert the raw crash risk increments to an estimate of the actual variation of crash risk for different HOS alternatives and industry segments. This is achieved by calibrating the crash risk increments for a base case to real-world fatigue related crash data. The procedure is identical to that described in Chapter 8 of the 2003 RIA report. The raw crash risk increments are the percentage increase in crash risk over the crash risk for a fully rested driver. Thus the proportional change in fatigue-related crashes between two HOS scenarios is represented by the ratio:

[100+crash increment for HOS option A]/[100+crash increment for HOS option B]

The base case for this analysis is the fatigue-related crash risk for LH truck operations under the 2003 HOS regulations, estimated at 7% of all truck involved crashes. The fatigue-related crash risk percentage for each of the HOS scenarios analyzed in this analysis is then as shown below:

$$\frac{7.0 \text{ x [100+crash increment for revised HOS option]}}{\text{[100+crash risk increment for 2003 HOS option]}}$$

The calculation is repeated for each HOS option analyzed.

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# 6. MODELING RESULTS

This chapter presents the results of the modeling of carrier operations under the options. The measured impacts of the HOS options on productivity are presented first, followed by a description of the weighting procedure used to combine the individual simulation runs into weighted average estimates of productivity impacts. These productivity changes are then translated into total cost estimates and changes in the number of drivers required. The next section presents and discusses in a parallel fashion the estimated crash risk impacts of the options for each run, the weighted impacts on crashes, and the value of those impacts.

Most of the analysis centers on the effects of the options on LH operations. Effects of the special provisions for smaller trucks in SH/local operations, which affect different entities and are estimated using a different approach, are covered briefly at the end of each section.

## 6.1 MEASURED PRODUCTIVITY IMPACTS OF OPTIONS ON LH OPERATIONS

Exhibit 6-1 shows the average percentage change in driving hours between Option 1 and the other options. The impacts of Options 2, 3, and 4, relative to Option 1, varied widely across the runs. Some patterns were readily apparent, however. The impacts tended to be greater for drivers assumed to take advantage of split sleeper berths, for both SR and LR drivers. This effect is expected, given that Option 1 allows drivers to enter their sleeper berths if they need to wait several hours before a load can be picked up or delivered. Because under Option 1 the use of the sleeper berth extends the 14-hour driving window, there are circumstances in which the drivers can be more productive, or can accept more advantageous loads. This use of the sleeper berth is more important if there are more waiting periods and less driving, which tends to be characteristic of operations with shorter lengths of haul. Thus, it is not very surprising that the relative impact of not having the split break available is absent for the LH cases (and the positive effect of eliminating the split break for LH drivers can be attributed to random elements in the simulation procedure). Overall, the loss of the split break appeared to be of minor importance for the productivity of solo drivers. This observation is likely due to the fact that, while the opportunity to initiate a split break provides flexibility, the rules for using this feature imparts rigidity to a driver’s schedule for subsequent tours of duty. For team drivers, we concluded that there was no necessary reason for a productivity impact from eliminating split break periods because two drivers alternating 10-hour driving periods can drive as much as two drivers alternating 5-hour driving periods (as discussed below, at the end of this section).

The relative productivity loss caused by Option 3 is substantially greater than that for Options 2 and 4 in almost all cases. This pattern comes from the fact that the important difference between these options is the length of the restart period. For the random drivers, the lack of a regularly scheduled off-duty period means that a short restart can be very advantageous, especially for the hard-working drivers that were modeled. The exceptions to this trend can be explained by the reduced value of the restart in particular cases. The regular weekly and daily routes (which generally have a full weekend off), and team drivers (who share duty hours each day) do not need to restart because their cumulative 8-day on-duty totals do not reach 70 hours. Finally, it should be noted that the one case of a negative measured impact of Options 3 and 4 are artifacts of the random elements in the simulation procedure, and would not be expected to persist if these runs were repeated a large number of times.

**Exhibit 6-1**
**Estimated Changes in Long-Haul Productivity by Option and Case**

| | | | Option 2 Compared to Option 1 | Option 3 Compared to Option 1 | Option 4 Compared to Option 1 |
|---|---|---|---|---|---|
| Run characteristics | | | Relative Reduction in driving hours | | |
| For-hire, random | Using split sleeper berths | Short Regional | 1.1% | 24.9% | 10.3% |
| | | Long Regional | 5.9% | 26.2% | 19.4% |
| | | Lon Haul | -3.1% | 17.9% | 9.6% |
| | | | | | |
| | No split sleeper berths | Short Regional | 0% | 24.1% | 9.3% |
| | | Long Regional | 0% | 21.4% | 14.2% |
| | | Long Haul | 0% | 20.4% | 12.5% |
| Regular Routes (Private TL, LTL, regular for-hire) | Full weekend off | Weekly route | 0% | 16.1% | 5% |
| | | Daily route | 0% | -2.0% | -1% |
| | Six-day work week | weekly route | 0% | 29.2% | 19% |
| | | Daily route | 0% | 8.9% | 10% |
| Team drivers* | Using split sleeper berths | | 0% | 5.0% | 5.0% |
| | No split sleeper berths | | 0% | 5.0% | 5.0% |

* These impact estimates were based on simplified scenarios rather than model runs.

For Options 3 and 4, the team drivers were expected to lose 5 percent of their productivity as a result of the loss of the 11th hour of driving. This impact could occur despite the fact that teams are not expected to use more than 10 hours per day per driver on average. We found a consensus among industry observers[40] that teams, on average, do not exceed 20 hours a day of driving. The average team driver, therefore, does not exceed an average of ten hours of driving in 24 hours on the clock. It does not, however, follow from this that there is no productivity loss for team operation from eliminating the 11th hour of driving.

The cost stems from the fact that a driver is very unlikely to find a suitable place to stop at the precise moment that his tenth driving hour ends. As long as he can use part of the 11th hour, this is not a problem. A driver can take what he deems as a convenient opportunity to stop, whether before or after the end of the tenth hour. The driver’s convenience and the spacing of stopping places would mean some driving tours over ten hours and some under. Team members’ driving times, then, would approximate an average of ten hours.

The result is different, however, when the drivers are limited to ten hours each. Since they cannot drive after ten hours, they must stop, effectively, before ten hours. Thus, the average driving time for each team member is necessarily less than ten hours; a few driving tours might end very close

[40] See section 2.1.6

to ten hours, but many would have to be well short of that, possibly anywhere in the range of nine to ten hours.

It is not feasible to offer a precise estimate of when in the nine-to-ten-hour range the average driver would stop. This would depend on the spacing of suitable stopping places on the route along which the team is moving. It also depends on what the team members would regard as suitable. Some gas stations have enough paved area for an 18-wheel tractor-trailer to park quickly. When one of the drivers is approaching the ten-hour limit, however, it is very likely that the vehicle has been moving for four or five hours and both team members would prefer more extensive facilities than a gas station would offer. Truck stops will be considerably less closely spaced along a highway than gas stations. To be conservative, we have assumed that the team will pass only one truck stop in the tenth hour and that could happen at any point in that hour. On this basis, the average driving time for each team member would be 9.5 hours rather than 10, a reduction of 5 percent.

In contrast to the expectation that a reduction in driving hours would reduce the productivity of teams, we concluded that eliminating split breaks would not affect their productivity. It is true that the splitting of breaks is common for teams, with drivers alternating moderately short driving and sleeper berth periods, interspersed with shorter periods in which the truck is stopped. For example, the first team member could drive for five hours, followed by a one-hour rest period for both drivers. The second member could then drive for five hours and stop for one hour, while the first member rested in the sleeper berth. Repeating this pattern, each driver could average 10 hours of driving per 24, which is as much productivity as is expected from teams (as discussed in Section 2.1.6).

We have found, however, that the same productivity can be achieved by a team that does not split, by alternating ten-hour driving and break periods (again, interspersed with short periods in which neither member of the team is driving). This pattern might start with five hours of driving by the first member, followed by a one-hour break, and then a second five-hour driving shift by the same driver. After another one-hour break, the first member of the team would stay off-duty, while the second member would begin a five-hour driving shift. After two driving shifts by the second driver, with a one-hour stop in between and another one-hour stop after the second shift, the entire pattern could be repeated. Thus, in each 24 hours, each team member would be able to drive an average of 10 hours, in two shifts with a short break in between, and each driver would have an uninterrupted off-duty period of 13 hours. This schedule is just as productive as the schedule that involves splitting – a total of 20 hours of driving out of 24. Some team members might find it more onerous to drive for 10 hours following a long break than to alternate shorter driving shifts with shorter breaks, but it is clear that solo drivers are capable of longer periods of driving between extensive off-duty periods. Thus, although many team drivers might prefer the flexibility allowed by split sleeper berth periods, we were unable to attach a productivity gain to this preference.

### 6.2 WEIGHTING OF THE INDIVIDUAL RUNS

Because the impacts of the options in the individual runs varies so widely, it was important to find the weighted average impacts across the runs, rather than relying on unweighted averages or simply presenting the range. The weighting procedure was based, in the first instance, on estimates of the fraction of total VMT accounted for by each operational pattern. Teams, for example, account for about 9 percent of total LH VMT, and LTL over-the-road operations account for another 5 percent. The remaining VMT is split roughly equally between for-hire and private fleets – 42 and 44 percent respectively. As noted in Chapter 2, we have found that about 60 percent of for-hire VMT can be considered random as opposed to regular. Furthermore, long regional and long haul operations are of greater magnitude than shorter operations, with about 38, 42, and 20 percent of VMT for these operational categories, respectively. We have also found that more than half of for-hire operations, and somewhat less than half of private fleet operations, are intensive enough to press the HOS limits, and should therefore be affected by changes in those limits.

In addition to representing the typical patterns in the industry, however, it was important that the modeling reproduced the usage of the important features of the HOS rules that differ between the options. To ensure that the weighting resulting in an accurate reflection of the use of these features (and therefore that the impacts of the options is realistically measured), the weights were altered to some degree, relying on data such as that shown in Exhibit 6-2, below. To match our estimate of the aggregate degree to which the 11$^{th}$ hour was used across the industry, we increased the assumed percentage of operations that were intensive enough to be affected by changes in the HOS rules beyond the degree indicated by the data. In the case of random TL operations, only a slight decrease (from 65% to 58%) was needed. In the case of regular operations, it was necessary to increase the assumed degree of intensive operations to 45%, compared to the 31% that emerged strictly from our analysis of the data in the FMCSA survey.[41]

To calibrate the results to match the percentage of drivers taking advantage of the split sleeper berth provision, we compared data on the percentage of times that actual drivers appeared to use the provision to the same measure for the simulated drivers in runs that allowed splitting. The degree of use of the split sleeper berth provision appears to vary widely, and is generally difficult to estimate; we approximated its use by assuming that it was used on an average of 13 percent of breaks by random-schedule solo drivers, and half of breaks by team drivers. We did not model solo drivers with regular schedules splitting their break periods, in part because we expected that the ability to plan and set up repeating schedules would reduce the value of the flexibility offered by splitting. In addition, as mentioned in Appendix (I), survey data showed considerably less splitting by drivers with regular schedules than by those with random schedules, and very little splitting overall. Finally, we expected that, even if some splitting occurs within this industry segment, it is likely to be related more to driver convenience than to an effort to enhance productivity. On the whole, there is considerable uncertainty about the actual extent to which splitting occurs, and the modeling procedure and weighting used for this study could have understated it. We have found, however, that because splitting did not show major productivity impacts, the estimate of the costs of the options are not very sensitive to inaccuracies of this kind.

[41] See Exhibit A-4. This increase in the percentage of the regular drivers that work intensively could result in an overstatement of the impacts of the options, particularly Options 3 and 4, if private fleets actually have relatively little intense operation. On the other hand, data used for the previous RIA (see Exhibit C-1, p. C-3 of the appendices) found a relatively small difference in intensity of effort between for-hire and private fleet operations – 44% to 46% and 32% to 37%, respectively – which we expect to track differences between random and regular operations. Thus, it may be that the FMCSA survey data understates the intensity of regular operations to some degree.

## 6.3 WEIGHTED LH PRODUCTIVITY IMPACTS

The weights used in the modeling are shown in Exhibit 6-3. This table also shows each operational type's contribution to the nationwide weighted impact, which is calculated by multiplying the relative impacts in Exhibit 6-1 by the weights.

The sums of these weighted contributions are also shown at the bottom of the table. Option 2 was found to reduce average driver productivity by only 0.042 percent, while the impacts of Option 3 was many times greater, at 7.1 percent. Option 4 was found to have an impact intermediate between 1 and 3, at 4.6 percent. Multiplying these weighted average productivity impacts by the costs per percent decrease in productivity presented in Chapter 4 – $298 million – yields $13 million per year for the incremental effect of Option 2. Option 3's impact, again relative to Option 1, is estimated to be $2,121 million on an annual basis. Finally, the impact of Option 4 relative to Option 1 is estimated to be $1,374 million per year.

**Exhibit 6-2**
**Use of the 11th Hour by Run**

<table>
<tr><th colspan="3"></th><th>Percentage of Tours with More than 10 hours of Driving in Option 1</th></tr>
<tr><th colspan="3">Run Characteristics</th><th></th></tr>
<tr><td rowspan="7">For-hire, random</td><td rowspan="3">Using split sleeper berths</td><td>Short Regional</td><td>0%</td></tr>
<tr><td>Long Regional</td><td>10%</td></tr>
<tr><td>Long Haul</td><td>21%</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td rowspan="3">No split sleeper berths</td><td>Short Regional</td><td>0%</td></tr>
<tr><td>Long Regional</td><td>11%</td></tr>
<tr><td>Long Haul</td><td>28%</td></tr>
<tr><td rowspan="4">Regular routes (Private TL, LTL, regular for-hire)</td><td rowspan="2">Full weekend off</td><td>Weekly route</td><td>31%</td></tr>
<tr><td>Daily route</td><td>55%</td></tr>
<tr><td rowspan="2">Six-day work week</td><td>Weekly route</td><td>29%</td></tr>
<tr><td>Daily route</td><td>34%</td></tr>
<tr><td rowspan="2">Team drivers*</td><td colspan="2">Using split sleeper berths</td><td>50%</td></tr>
<tr><td colspan="2">No split sleeper berths</td><td>50%</td></tr>
</table>

*Estimates for team drivers are based on simplified assumptions rather than modeling.

As presented in Chapter 4, retraining is expected to add an annualized $21 million to the costs of Options 2, 3, and 4. Thus, the total annual incremental costs for Option 2 is $13+$21 = $34 million, for Option 3 is $2,121 + $21 = $2,142 million. These estimates are summarized in Exhibit 6-4.

**Exhibit 6-3**
**Weighted Changes in LH Productivity by Option and Case**

| | | | Weight | Option 2 Impact | Option 3 Impact | Option 4 Impact |
|---|---|---|---|---|---|---|
| **Run characteristics** | | | | | | |
| For-hire, random | Using split sleeper berths | Short Regional (SR) | 0.5% | 0.01% | 0.14% | 0.06% |
| | | Long Regional (LR) | 1.2% | 0.07% | 0.32% | 0.24% |
| | | Long Haul (LH) | 1.2% | -0.03% | 0.21% | 0.11% |
| | | | | | | |
| | No split sleeper berths | SR | 2.4% | 0.00% | 0.57% | 0.22% |
| | | LR | 4.9% | 0.00% | 1.05% | 0.70% |
| | | LH | 4.4% | 0.00% | 0.89% | 0.55% |
| Regular routes (Private TL, LTL, regular for-hire) | Full weekend off | Weekly | 6.9% | 0.00% | 1.11% | 0.32% |
| | | Daily | 7.9% | 0.00% | -0.15% | -0.06% |
| | Six-day work week | Weekly | 5.9% | 0.00% | 1.73% | 1.15% |
| | | Daily | 8.9% | 0.00% | 0.79% | 0.88% |
| Team drivers | Using split sleeper berths | | 4.5% | 0.00% | 0.23% | 0.23% |
| | No split sleeper berths | | 4.5% | 0.00% | 0.23% | 0.23% |
| Unaffected (due to less-intense schedules) | | | 45.1% | 0.00% | 0.00% | 0.00% |
| Total | | | 100.0% | 0.042% | 7.12% | 4.61% |

## 6.4 COST IMPACTS OF THE OPTIONS ON SH OPERATIONS

The analysis concentrates on the LH segment of the motor carrier industry because the major HOS provisions differentiating the options are expected to have little or no effect on local and SH operations. Drivers who stay within a short radius of their base of operations and return home every evening will have no use for the sleeper berth provisions, and will very rarely be able to drive more than 10 hours in a tour of duty because of the number of stops for waiting, loading and/or unloading that are typical for local and SH operations. Furthermore, because local/SH drivers generally have weekends off and less intense schedules, changes in the restart provisions will make relatively little difference to their productivity.

**Exhibit 6-4**
**Incremental Annual Costs of the Options for LH Operations Relative to Option 1**

| | Option 2 | Option 3 | Option 4 |
|---|---|---|---|
| **Change in LH Productivity** | 0.042% | 7.12% | 4.61% |
| **Change in Annual Costs due to Productivity Impact (millions of 2004$)** | $13 | $2,121 | $1,374 |
| **Incremental Annualized Retraining Cost (millions of 2004$)** | $21 | $21 | $21 |
| **Total Annual Incremental Cost** | $34 | $2,142 | $1,395 |

Source: ICF analysis.

Two provisions of Options 2, 3, and 4, however, affect only local/SH drivers: the exemption from keeping log books, and a second 16-hour day in each week. These two provisions apply only for drivers of vehicles between 10,000 and 26,000 lbs. GVW that stay within a 150 air-mile radius of their base of operations, and return to that base at the end of each tour of duty.

We have estimated the cost impacts of these provisions by dividing local/SH vehicles into a limited set of cases, determining the time savings of the log-book exemption for each vehicle in each case, and valuing those savings per vehicle. We then estimated the number of vehicles in each case, multiplied by the savings per vehicle, and summed across the cases.

We estimated the savings from the second 16-hour day per week using a variant of the analysis of the savings from the first 16-hour day per week, which was conducted for the 2003 RIA. Those estimated savings were translated into an annual per-vehicle value, and then scaled appropriately for our estimate of the number of affected vehicles.

A summary of the results of these cost analyses is shown in Exhibit 6-5. Details on the analysis are presented in Appendix (IV).

**Increases in Drivers**

If the same total ton-miles of freight would be transported by truck under all four options, the reductions in LH productivity could be translated directly into percentage increases in the number of drivers needed by the industry. Thus, Option 2 would require an additional 0.042% *1.5 million or about 600 long-haul drivers, Option 3 would require an additional 7.12% * 1.5 million or 107 thousand, and Option 4 would require 4.61 * 1.5 million or 69 thousand.

As discussed in Chapter 4, however, reduced productivity could be expected to raise the trucking rates slightly, leading to slightly more competition from rail. We estimate that the resulting mode shift would cut the need for additional drivers slightly.

**Exhibit 6-5**
**Summary of Local/SH Analysis**
**(Annual Savings in Millions of 2004$, rounded to the nearest $10 million)**

| | **Case 1** | **Case 2** | **Case 3** | **Total Annual Savings (millions)** |
|---|---|---|---|---|
| Description | Now operating within 100-mile range and not keeping logs. Duty tours ≤ 12 hours. | Now operating within 100-mile range and keeping logs. Duty tours up to 14 hours. | Now operating in 100-150 mile range. Must keep logs and observe 14-hour limit. | |
| Log-book effects | No effect; already exempt from log requirement. Benefit: $0 | Relieved from log requirement. Benefit: $100. | Relieved from log requirement. Case-3 benefit: $40 | $140 |
| 14-hour tour with log-book exemption | May use 14-hour tour now, if they keep log. Tour>12 hours is of little value to this group. Benefit: minimal | Already choosing log-book and 14-hour tour. Benefit: zero | Already have 14-hour tour. | $ 0 |
| | **Case 1** | **Case 2** | **Case 3** | **Total Annual Savings (millions)** |
| Second 16-hour day | Would not use the 16-hour day because they already choose not to use the 14-hour tour. Savings: $0 | Analysis is an extension of analysis of second 16-hour day that was done for the 2003 RIA. This approach did not distinguish between Cases 2 and 3. Productivity Benefit: $140 | | $140 |
| Total | | | | $280 |

Source: ICF analysis. See Appendix (IV).

### 6.5 CRASH RISK RESULTS BY OPERATIONAL CASE

The results of the crash risk modeling are presented in Exhibit 6-6, with and without scaling the results to yield an average fatigue-related value of 7 percent in Option 1. Overall, the impacts are relatively small, as might be expected for options that are making marginal changes in an existing rule. Some patterns are visible: in almost every case, Options 2, 3, and 4 show lower crash risks than Option 1. In most cases, the crash risk reductions were greater for six-day schedules than for five-day schedules.

Options 3 and 4 have generally greater reductions in risks (shown as negative numbers) than Option 2, as is expected due to the greater stringency of those options. Impacts on team drivers, which were modeled as being the same for Options 3 and 4, were greater for drivers who split their rest periods under Option 1 than for those who did not.

There are also some anomalies in the results. In the random schedule cases, the advantages of Options 2, 3, and 4 over Option 1 were not uniformly greater for drivers inclined to split their rest periods: this was the case for short-regional drivers but not for long-regional or long-haul drivers. There was no overall tendency for Option 3 to out-perform Option 4. As discussed in Chapter 5, however, the advantage of Option 3 over Option 4 (which lies in the extra 14 hours of rest over the weekend) are expected to be very small for well-rested drivers, and it is likely that this small expected advantage was masked by the random factors inherent in the modeling. Random factors in the modeling may also have resulted in an apparent disadvantage for Option 2 over Option 1 for long-regional and long-haul operations, while possibly overstating the impacts on short-regional operations. Because of these random factors, the weighted average impact over all three operational types is likely to be more accurate than any of the individual measures. For those operations that split rest periods, the weighted average impact showed a slight reduction in crash risk.

Weighting the crash risk results in the same manner as the productivity results, we found the overall changes in crash risks to be small. Option 2 resulted in a risk reduction of about 0.1 percent, while Options 3 and 4 each provided a risk reduction of about 0.6 percent.

### 6.6 VALUE OF THE LH CRASH RISK CHANGES

These percentage changes in risk were valued by multiplying them by an estimate of the total annual damage associated with heavy-duty long-haul truck crashes. For consistency with the earlier analysis, we have used the value from the previous analysis of $32.2 billion in year 2000 dollars, or about $34.9 billion in year 2004 dollars. The 2003 RIA also presented an estimate of the percentage of total damages that were caused by the long-haul segment. Applying the same percentage – just over 58 percent – to $34.9 billion yields just over $20 billion. The reduction in risk attributable to Option 2, given this total value, is 0.1% * $20 billion or about $20 million per year. The value of the risk reduction attributable to Options 3 and 4 is higher, at 0.6% * $20 billion or about $120 million per year. These risk reduction changes are much smaller than the cost changes attributable to the options.

We expect the crash risk impacts of the local/SH changes to be negligible. The analysis of the crash risk impacts of a single 16-hour day for SH drivers in the 2003 RIA, which showed a $10 million annual increase in benefits because the productivity improvement it would provide would reduce the need to hire new, less experienced drivers.[42] Because the second 16-hour day is estimated to be used considerably less than the first, we conclude that the risk impacts of the second 16-hour day would be essentially zero.

[42] See p. 9-9 of the 2002 RIA.

**Exhibit 6-6**
**Incremental Crash Risk Estimates**

| | | | Option 2 Compared to Option 1 | Option 3 Compared to Option 1 | Option 4 Compared to Option 1 |
|---|---|---|---|---|---|
| Run characteristics | | | Relative Change in Crash Risk | | |
| For-hire, random | Using split sleeper berths** | SR | -7.4% | -6.3% | -2.4% |
| | | LR | 1.4% | -5.6% | -7.5% |
| | | LH | 2.0% | -7.2% | -7.6% |
| | | | | | |
| | No split sleeper berths | SR | 0% | 1.1% | 5.0% |
| | | LR | 0% | -6.9% | -8.9% |
| | | LH | 0% | -9.3% | -9.6% |
| Regular routes (Private TL, LTL, regular for-hire) | Full weekend off | Weekly | 0% | 0.2% | -0.4% |
| | | Daily | 0% | -0.7% | -0.3% |
| | Six-day work week | Weekly | 0% | -0.7% | -1.2% |
| | | Daily | 0% | -0.9% | -0.5% |
| Team drivers* | Using split sleeper berths** | | -5.7% | -6.4% | -6.4% |
| | No split sleeper berths | | 0% | -0.7% | -0.7% |
| Weighted Average Impacts (raw) | | | -0.3% | -1.4% | -1.4% |
| Weighted Average Impacts (scaled) | | | -0.1% | -0.6% | -0.6% |

*Based on ICF analysis of simplified scenarios.

**These scenarios assumed time-on-task effects for split sleeper berth cases are of the same magnitude as in equivalent non-split cases. Reductions in crashes would be smaller if split rest periods eliminate time-on-task effects.

## 6.7 NET COSTS BY OPTION

Exhibit 6-7 summarizes the annualized costs, benefits, and net costs of each of the options relative to Option 1. Both LH and local/SH effects are shown. The values have been rounded to the nearest $10 million, in line with the values presented for the local/SH impacts.

**Exhibit 6-7**
**Net Incremental Annual Costs of the Options Relative to Option 1**
**(millions of 2004$, rounded to nearest $10 million)**

| | | Option 2 | Option 3 | Option 4 |
|---|---|---|---|---|
| **Total Annual Incremental Cost** | **LH** | $30 | $2,140 | $1,390 |
| | **SH** | -$280 | -$280 | -$280 |
| **Total Crash Reduction Benefits** | **LH** | $20 | $120 | $120 |
| | **SH** | ~0 | ~0 | ~0 |
| **Net Annual Costs** | | -$270 | $1,740 | $990 |

### 6.8 LIMITATIONS AND SENSITIVITIES

The estimates of costs and benefits of the options relative to one another are based on data, assumptions, and modeling, each of which are subject to uncertainties of various kinds. We have estimated the effects on the cost and benefit calculations if variants of some of the assumptions used in the analysis were used.

#### 6.8.1 Elimination of the 11th Hour of Driving in Option 2

In addition to Options 1, 2, 3, and 4, we also examined a more restrictive variant of Option 2. That option limited driving to 10 hours in a tour of duty, in addition to the restrictions on the splitting of break periods that constitute the difference between Option 2 and Option 1. This more restrictive option was found to provide more benefits than Option 2, but at substantially higher cost. Crash risks were found to be reduced by about 0.4 percent rather than 0.1 percent, providing about $80 million in annual benefits (20+60) compared to the $20 million provided by Option 2. The projected cost impacts, however, rose by $586 million per year.[43] The minimal financial impacts of Option 2 would increase, spreading the possibility of significant adverse impacts over a much larger portion of the industry. To summarize the effects of restricting driving to 10 hours, we will compare the net of costs and benefits of this restrictive variant of Option 2 to the net for the original Option 2.[44] Exhibit 6-7 shows that the benefits of Option 2 exceed its costs, leading to net annual benefits of $270 million. For Option 2 with 10 hours of driving, total costs become +$336 million annually (+30-280+586) and total benefits are $80 million annually, as just mentioned. As a result, under Option 2 with 10 driving hours, the net annual cost is $256 million annually. The analysis concludes that Option 2 is far more cost-beneficial than that option with 10 driving hours: a net benefit of $270 million annually rather than a net cost of $256 million.

Because various factors and assumptions that feed into the analyses of benefits are uncertain, the costs and benefits of the incremental elimination of the 11th hour could be higher or lower than $586 million and $60 annually. To test whether reasonable changes in the most important assumptions could swing the overall cost-benefit analysis to favor 10 hours in Option 2, we have conducted sensitivity analyses that change each of several key assumptions in turn, and another in which they are changed as a group. The first two single-assumption sensitivity analyses make changes that favor eliminating the 11th hour of driving. These two sensitivity analyses test whether or not Option 2 is still cost-beneficial relative to Option 2 with 10 hours of driving. In other words, we "stress test" the cost-benefit analysis of Option 2 by testing whether unfavorable assumptions would reverse the selection of Option 2 in favor of its more-restrictive variant.

**Value Per Statistical Life Saved**

Crash reduction benefits were estimated based on examinations of the outcomes of crashes (property damage only, injuries and property damage, or fatalities) and detailed assessments of the social costs of those outcomes. Repair costs, costs of medical treatment, lost time due to delays, and productivity losses due to injuries and deaths are all included. In addition, deaths are valued by computing how many “quality adjusted life years” the victims lose. In the study used

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[43] Compared to the $60 million increase in benefits, the increase in costs is almost ten times as great.

[44] Net benefits = benefits – costs. Net costs = costs - benefits

as the basis for the benefits analysis in the 2003 RIA, the value per statistical life saved in large truck crashes was very close to $3 million.[45] In 2004, the Office of Management and Budget (OMB) issued updated guidance to Federal agencies with regard to conducting regulatory impact analyses, including information on the monetary value of a statistical life (VSL). In this guidance, OMB indicated that, "A substantial majority of the resulting estimates of VSL vary from roughly $1 million to $10 million per statistical life." [OMB Circular A-4, p.30].

If a higher value were assumed for avoiding each fatality, the total benefits for reducing crashes through the elimination of the 11th hour of driving would rise, and the net benefits of Option 2 with 10 hours would increase. The effect of raising the value per statistical life saved from $3 million to $10 million, the upper limit of the range recommended by OMB, can be calculated using the total annual damages from all truck-related crashes and the total number of fatalities in those crashes. As presented in Chapter 6, the total cost associated with truck crashes is $34.9 billion per year. The portion of this total due to fatalities, assuming $3 million per fatality, is $3 million * 5,346 or just over $16 billion, where 5,346 is the average annual number of fatalities in truck-related crashes (as reported in Exhibit 8-1 of the 2003 RIA). If the value of a statistical life is taken to be $10 million instead of $3 million, the total cost associated with the fatalities rises to about $53.4 billion, an increase of about $37.4 billion. The total damages from all truck related crashes, then, rise to $34.9 + $37.4 billion or $72.3 billion. Using this value of damages in place of the original $34.9 amounts to an increase by a factor of 72.3/34.9, or 2.07.

The larger VSL would thus increase total benefits for Option 2 with 10 hours from $80 million annually to $166 million.[46] Since the annual costs of Option 2 with 10 hours are unchanged at $336 million, the net cost becomes $170 million (336-166). The $170 million net cost with a higher VSL, while better, is still much less cost-beneficial than under Option 2, which increases from $270 million of net benefits to about $311 as a result of the increase in the VSL. Although more than tripling the VSL does lower the net cost, eliminating the 11th hour of driving in Option 2 is still not cost-beneficial.

**Increased Relative Risk from the 11th Hour**

As explained in Chapter 5, the benefits of eliminating the 11th hour were calculated using an added TOT multiplier for crash risks for long hours of driving. The magnitude of this multiplier was calculated on the basis of TIFA data for over 30,000 fatal crashes. The analysis measured the percentage of fatal crashes considered to be fatigue-related as a function of number of hours behind the wheel since an extended break. The fatigue-related percentage was low for the first six or seven hours, and then generally increased with each additional driving hour. Breaking the data into 13 categories – 1 hour through 12 hours, and then combining those few data points beyond 12 – we found that the fatigue-related percentage could be described well as a cubic function of TOT: the cubic equation explained more than 98 percent of the variability in the

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[45] "Costs of Large Truck-and –Bus Involved Crashes", Zaloshnja et al (2000) pg. 21 Table 11. This table shows a cost per fatal crash of about $3.4 million in 2000 dollars, almost all of which was due to the loss of quality adjusted life years and lifetime earnings After adjusting to 2004 dollars and dividing by the average number of fatalities per crash, the damage per statistical life is very close to $3 million.

[46] $166 million = $80 million x 2.07

grouped data showing the fatigue-related percentage. Using this equation, driving in the 11th hour entails a fatigue-related crash risk that is about 2.5 times as great as the average for the entire 11 hour trip.

Because the regression equation was based on a sample of data and is only an estimate with error, the true relative risks of fatigue involvement in the 11th hour could be higher or lower. To estimate how much higher this relative risk is likely to be, a "bootstrap" analysis of the data set was conducted.[47] In this analysis, the regression equation was re-estimated 500 times, using data sets randomly selected from the thirteen original points, reflecting the grouped data.[48] Across these 500 equations, the upper bound of the 95 percent confidence interval (between the 12th and 13th highest out of 500) was 3.15, which is about 25 percent higher than the original estimate of relative risk, and the upper bound of the 99 percent confidence interval (the 5th highest out of 500) was 3.56, which is about 40 percent higher than the original estimate. Thus, there is only a 1% chance that the additional risk caused by driving in the 11th hour is more than about 1.4 times greater than the estimate used in the cost-benefit analysis of Option 2 that appears in Exhibit 6-7.[49]

If the risk caused by allowing operators to drive for 11 hours is, in fact, 1.4 greater than had been assumed in the cost-benefit analysis of Option 2, then the benefits for Option 2 with only 10 driving hours would rise from $80 million to $104 million annually (i.e., from $20 + $60 to $20 + $60 * 1.4, because the factor of 1.4 would affect only $60 million in benefits related to elimination of the 11th hour.). Increasing the 11th hour driving risk does not change the cost of Option 2 with 10 hours, which remains at $336 million annually. Consequently, under the higher risk of driving the 11th hour, the net cost of Option 2 with 10 hours becomes $232 million per year (or $336 - $104). Thus, while increasing the relative risk of a fatigue-related crash while driving the 11th hour does reduce the net costs, eliminating the 11th hour is still not cost-beneficial. Conversely, with a net benefit of $270 million annually, Option 2 with 11 hours of driving is still the preferred option compared to alternative Option 2 (i.e., with 10 hours driving), even when assuming a heightened relative risk of fatigue crash in the 11th driving hour.

**Overall Use of the 11th Driving Hour**

The two sensitivity analyses above stress-tested Option 2 by making plausible changes in assumptions that favored eliminating the 11th driving hour. We next made a sensitivity analysis of changing another key parameter--the use of the 11th driving hour. Reducing the use of the 11th

[47] The bootstrap regression procedure was implemented in Microsoft Excel, using a methodology developed in the statistical software Stata" StataCorp, 2001. Stata Statistical Software: Release 7.0. College Station, TX: Stata Corporation.

[48] A bootstrap analysis samples the original dataset with replacement, which means that it creates a new dataset with the same number of observations as the original dataset. After each data point is randomly selected as part of an individual data set, it could be chosen again in the same dataset. The variation introduced by this method allows for the calculation of confidence intervals for the regression parameter estimates, and therefore a confidence interval for the relative risk of the 11th hour of driving.

[49] We acknowledge that this type of analysis explicitly identifies one major contributor to the uncertainty of the estimate (sampling error) but does not explicitly correct for more general sources of uncertainty, such as whether or not this relative risk estimate is an unbiased estimate of the true risk of the 11th hour of driving for the reasons discussed earlier in the analysis. Implicitly, however, the increase in relative risk identified by this sensitivity analysis could also be due to a downward-biased original estimate, or indeed any other source of uncertainty.

hour would move the cost-benefit analysis toward Option 2 with 10 hours, but we could not plausibly make that assumption: as the 11th hour of driving becomes more incorporated into normal operations in the future, we believe its use much more likely to increase rather than decrease. Increasing that percentage would increase the costs to the same degree as the crash reduction benefits. For example, a doubling of the percentage would lead to estimated costs for Option 2 with 10 hours of about +$922 million (+30-280+1,172, where 1,172=586*2). Benefits for Option 2 with 10 hours would become $140 million annually (+20+120; where 120=60*2). Net costs for Option 2 with 10 hours would rise from $256 million annually to $782 million annually. If the use of the 11th driving hour doubled, Option 2 with 10 hours would become even less cost-beneficial relative to the original Option 2. Also note that even if the use of the 11th hour dropped, because the use of the 11th hour is cost-beneficial regardless of how often it is used, variation of this single assumption could never make the restriction of the 11th hour of driving cost-beneficial. In other words, this assumption is not decision critical with regard to whether or not to restrict the 11th hour of driving.

**Baseline Risks of Fatigue-related Crashes**

One important reason that the cost-effectiveness of banning the 11th hour is unfavorable, despite the fact that fatigue-related crashes rise to several times their average value as TOT increases, is that fatigue is associated with only a fraction of all crashes. Thus, even if fatigue-related crashes are two to three times as likely in the 11th hour as in the average hour, the overall change of a crash increases only moderately. For the 2003 RIA, fatigue was estimated to cause 8.15 percent of crashes. If in a given hour that risk increases by a factor of 2.5, to about 20.4 percent overall, then overall crash risks in that hour would rise by only about 12 percent. In addition, because the 2003 rule was estimated to reduce fatigue-related crashes considerably, the incremental effect of the 11th hour would be even smaller.

There is, however, uncertainty about the baseline degree of fatigue. In the 2003 RIA, sensitivity analyses were prepared using alternative assumptions of 5 and 15 percent, in addition to 8.15 percent, because most comments relating to the prevalence of fatigue as a cause of accidents posited values within that range. If the 15 percent value were used for the baseline (in the pre-2003 situation), the estimated crashes caused by fatigue would rise by a factor of 15/8.15 or 1.84 (i.e., an increase of 84 percent of the base). This increase would carry through to the impact of both the splitting of rest periods and eliminating the 11th hour, meaning that assuming a higher baseline fatigue percentage would raise the benefits from $80 million to $80 * 1.84, or $147 million. This change would imply net costs of $336 million - $147 million or about $190 million. Though increasing the baseline risk of fatigue-related crashes from 8.15 percent to 15 percent does reduce the annual net cost (from $256 million to $147 million), eliminating the 11th hour of driving in Option 2 is still not cost-beneficial.

**Combinations of Changes in Assumptions**

None of the sensitivity analyses described above show a balance of costs and benefits that supports Option 2 with driving restricted to 10 hours. These sensitivity analyses were all conducted, however, with only one assumption changing at a time, and it is at least possible that the most realistic answer would be obtained if the three assumptions that moved the cost-benefit results toward eliminating the 11th hour were changed simultaneously. Take the combined sensitivity analysis for: (1) the value of a statistical life assumed to be at the high end of its range ($10 million, instead of $3 million); (2) the risk of the 11th hour assumed to be at the upper bound of the 99 percent confidence interval (about 1.4 times the value used in the basic analysis); and (3) the baseline fatigue percentage assumed to be at the high end of its range (15 percent instead of 8.15 percent). In that case, the total benefits of Option 2 with 10 hours of driving would be about $396 million per year.[50] while total costs would still be $336 million annually, leaving a net benefit of $60 million per year. Even in this extreme and unlikely case, however, the net benefit of Option 2 would be substantially more favorable at $326 million annually.[51] Thus, it appears highly unlikely that banning the 11th hour would lead to a cost-beneficial rule, even with all favorable assumptions.

These points are summarized in Exhibit 6-8, which presents the effects of different safety-related assumptions on the net costs, benefits, and net benefits of two versions of Option 2, relative to Option 1. Each pair of rows compares the Option with and without a 10-hour driving limit; the

**Exhibit 6-8**
**Sensitivity Analyses of Net Benefits, 10-hour Driving Limit**
**(millions of 2004$)**

| | Option | Net Costs Relative to Option 1 | Safety Benefits Relative to Option 1 | Net Benefits Relative to Option 1 | Net Benefits of Option 2 Relative to Option 2 w/10 hours |
|---|---|---|---|---|---|
| **Basic Assumptions** | Option 2 | -250 | 20 | 270 | |
| | Option 2 w/10 hrs | 336 | 80 | -256 | 526 |
| **Twice as Much Use of 11th Hour** | Option 2 | -250 | 20 | 270 | |
| | Option 2 w/10 hrs | 922 | 140 | -782 | 1052 |
| **Higher Value of Statistical Life (VSL)** | Option 2 | -250 | 41 | 291 | |
| | Option 2 w/10 hrs | 336 | 166 | -170 | 462 |
| **Higher TOT Impact** | Option 2 | -250 | 20 | 270 | |
| | Option 2 w/10 hrs | 336 | 104 | -232 | 502 |
| **Higher Baseline Fatigue** | Option 2 | -250 | 37 | 287 | |
| | Option 2 w/10 hrs | 336 | 147 | -189 | 476 |
| **Higher VSL, TOT Impact, and Baseline Fatigue** | Option 2 | -250 | 76 | 326 | |
| | Option 2 w/10 hrs | 336 | 396 | 60 | 266 |

[50] These more favorable assumptions would increase the part of total benefits associated with eliminating the 11th hour by a factor of about 2.07 * 1.4 * 1.84, or about 5.33, and would increase the rest of the benefits by a factor of about 2.07 * 1.84, or about 3.8. These changes would imply total benefits for Option 2 with 10 driving hours of about +$396 million per year (=60 * 5.33 + 20 * 3.8).

[51] The benefits of Option 2 would rise under these assumptions from $20 million per year to $20 million * 2.07 *1.84, or to $76 million, so net benefits would rise to $280 -30 + $76 million, or $326 million per year. One should also bear in mind that the impact of TOT in the 11th hour could be overstated as well as understated, and the baseline risk of fatigue could be lower than 8.15 as well as higher. These possibilities, which would make the cost-benefit analysis less favorable to dropping the 11th hour, were not considered explicitly in the sensitivity analyses.

column at the right shows the net advantage of Option 2 over the alternate version with the 10-hour limit. The first column of figures is the net cost of the two options relative to Option 1 under different assumptions; because only the change in the assumption about the use of the 11$^{th}$ hour has an effect on costs, very little changes in this column from one assumption to the next. The next column of figures shows the safety benefits of the options relative to Option 1; in general, the version of Option 2 with the 10-hour limit shows a greater increase in benefits in response to changing the safety assumptions, and shows the higher increase in the last row, which combines the preceding three changes in assumptions. The third column of figures is the difference between the previous two – in other words, the net benefits of the options. For each set of assumptions, Option 2 has positive net benefits relative to Option 1. Option 2 with a 10-hour limit shows positive net benefits relative to Option 1 only in the last row, which combines three assumptions that favor the driving restriction. Even in this case, however, the net benefits of Option 2 with the 10-hour limit are far lower than the net benefits of Option 2 without the 10-hour limit. The disadvantage of the 10-hour limit is brought home in the final column, which compares the two versions of Option 2 directly: even under the most favorable set of assumptions, Option 2 without the 10-hour limit has net benefits that are $266 million higher. Thus, even under the most favorable assumptions, eliminating the 11$^{th}$ hours does not appear to be cost-effective.

### 6.8.2 Impact of Splitting on the Time-on-task Effect

The safety analysis assumed that driving beyond the 8$^{th}$ hour since an 8-hour break leads to higher risks, due to a "time-on-task" (TOT) effect. This effect was assumed to manifest itself even for drivers who split their off-duty breaks: a 5-hour break, followed by 5 hours of driving, followed by another 5 hour break and another 5 hours of driving, was assumed to result in the same TOT effect as a 10-hour break followed by 10-hours of driving. This assumption might not hold, however. Someone who never drives for more than 5 hours without taking 5 hours off might experience only a 5-hour, not a 10-hour, TOT effect. Recalculating the safety benefits under the assumption that the TOT effect does not carry over from one split period to another, we found that the annual safety benefits for Option 2 would be reduced by $12 million per year, or more than half. The benefits for Options 3 and 4 would be reduced by about $17 million per year, or about 14 percent.

### 6.8.3 Impacts of Greater Splitting of SB Periods

Both the productivity and safety analyses assumed a limited degree of splitting of sleeper berth periods: 13 percent of random-schedule solo driving, 50 percent of team driving; none of the operations with regular schedules were assumed to split break periods for productivity reasons. Because these assumptions might understate the true amount of splitting, we recalculated costs and benefits assuming twice the use of split sleeper berth periods. This change in assumptions raised the annual benefits of all three options by about $20 million – a 100 percent increase for Option 2 and 20 percent for Options 3 and 4. Costs would increase by about $13 million, a reflection of the minor productivity advantages found for splitting for solo operations and the lack of an advantage assumed in our modeling of team operations.

### 6.8.4 Use of the 11th Hour of Driving by Local/SH Drivers

The analysis of costs and benefits assumed that the 11th hour of driving allowed under Option 1 was not used by local/SH drivers, on the basis of our understanding these operations and data that corroborated this understanding. We assumed, implicitly, that the few cases in which compliant drivers in local operations reported driving more than 10 hours in a tour of duty were erroneous: either regional drivers were classified as local because they returned to home base every night, or because non-driving time (e.g., during deliveries) was classified as driving for the convenience of the driver in keeping the log.

It may be, however, that this implicit assumption is incorrect, and there would be some impact on local/SH drivers from the elimination of the 11th hour. Taking the FMCSA survey data at face value, and assuming that 5 percent of all local/SH tours of duty exceeded 10 hours of driving, we estimate that Options 3 and 4 would reduce local/SH productivity by about 0.35 percent. Estimating the costs of this productivity impact using the same approach as for LH operations resulted in an estimated cost impact of about $90 million per year, which is less than a tenth of a percent of total local/SH revenues. Safety benefits would amount to approximately $5 million.

### 6.8.5 Uncertainty about Fatigue-related Crashes

Because of the difficulty of identifying the causes of crashes, there is considerable uncertainty about the percentage of crashes that can be attributed directly or indirectly to fatigue. The 2003 RIA included a sensitivity analysis showing the effects on the benefit estimates of substantial changes in baseline estimates of fatigue-related crashes. A similar sensitivity analysis would show benefit estimates for Option 2 as high as $37 million and as low as $12 million, for baseline fatigue risk estimates of 15 and 5 percent, respectively, in place of the 8.15 percent value used for the 2003 RIA. The benefit estimates for the other two options would range from just over $70 million to about $220 million.

Compliance

As noted earlier in this RIA, the baseline for the 2005 RIA analysis is the current operating environment (the 2003 rule), assuming full compliance with existing regulations. The baseline for the 2003 RIA was the operating environment at that time, or the pre-2003 rule, assuming full compliance by motor carriers with those regulations. The 2003 RIA also considered the effects of incomplete compliance in the baseline, relative to the full compliance baseline, but did not attempt to assess the possible degree of non-compliance with the option that was selected (and which has become Option 1, the baseline for this analysis). The supplemental (incomplete compliance) analysis performed as part of the 2003 RIA was performed due to the relatively broad scope and novelty of the three alternative regulatory packages considered as part of that rulemaking. As such, analyzing the economic impacts of the 2003 rule options from an alternative (incomplete compliance) baseline was appropriate. In contrast, the various regulatory options given serious consideration as part of the 2005 HOS rulemaking were much less sweeping in nature. For instance, under Alternative Options 2, 3, and 4 examined in this RIA, the regulatory choices were generally limited to returning to the pre-2003 rule environment (i.e., eliminating the restart provision (equivalent to 58 hours) and/or returning to 10 hours of daily driving) or revising provisions in that general direction (i.e., increasing the required minimum restart period to 44 hours). Given that the range of 2005 rule revisions were much less sweeping, FMCSA concentrated its analytical efforts on conducting a series of sensitivity analyses described above. FMCSA believes this more finely-grained (sensitivity) analysis was more appropriate here, given the relatively limited scope of the changes considered here.

## 7. FINANCIAL IMPACTS TO SMALL CARRIERS

This chapter, which constitutes the small business impact analysis, considers firm impacts on long-haul truckload carriers in seven size categories, which are shown below with estimates of the number of independent firms falling into each:[52] [53]

- 1 tractor (32,800 firms)
- 2-9 tractors (9,800 firms)
- 10-19 tractors (3,500 firms)
- 20-50 tractors (3,500 firms)
- 51-145 tractors (1,800 firms)
- 146-550 tractors (600 firms)
- 550+ tractors (150 firms)

Carriers in the first five of these categories generally qualify as small entities under criteria established by the Small Business Administration (i.e., annual revenue of less than $21.5 million) for all North American Industrial Classification System (NAICS) codes falling under the truck transportation sub-sector (NAICS 484). Carriers typically exceed this threshold when they operate about 145 tractors or more.[54] The largest two categories encompass those long-haul carriers that do not qualify as small entities under the SBA criteria. The specific size categories enumerated above are intended to reflect natural groupings or breakpoints in terms of firm behaviors and economies of scale.

For representative carriers in each size category, the study estimated the financial impact of each HOS rule option in terms of the change in net income (in 2004$) to the carrier,[55] as well as a change in their profits as a fraction of operating revenues. The approach used to estimate these impacts, which involved the development of a pro forma financial model of firms of different sizes confronted by changes in productivity, wages, and prices, is presented in detail in Appendix H of the 2003 RIA. The distribution of carriers by size category is summarized in Chapter 3 of that RIA.

This analysis used two industry-specific data sources in developing the firm-level data inputs to the general pro forma model. Annual TTS Blue Book financial data was used as the basis for determining the impact of the change in hours of service regulations on a variety of firm sizes. However, the Blue Book data only includes firms with revenues greater than $3 million per year (approximately 20 tractors). For firm sizes less than this, data from the Risk Management Association (RMA) were used for firms with $0 to 1 million (assumed to represent firms with 2-9 tractors) and $1 to $3 million (assumed to represent firms with 10-19 tractors).

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[52] Impacts on the private fleets are not expected to be significant. In the case of private fleets, firm impacts generally will be relatively small because trucking comprises only a small portion of firm activities. Furthermore, the options have only slight, and positive, effects on SH costs relative to the baseline (2003 rule).

[53] See Chapter 3 and Appendix A of the 2003 RIA for details on the method used to prepare these estimates.

[54] Based on analysis of data from the TTS Blue Book. This implies total revenue (i.e., from trucking plus other value-added services) averaging approximately $145,000 per tractor across all firm sizes.

[55] Representative carriers for the four largest size categories were selected on the basis of having the median value in the category for profitability (as measured by the ratio of net income to total revenue).

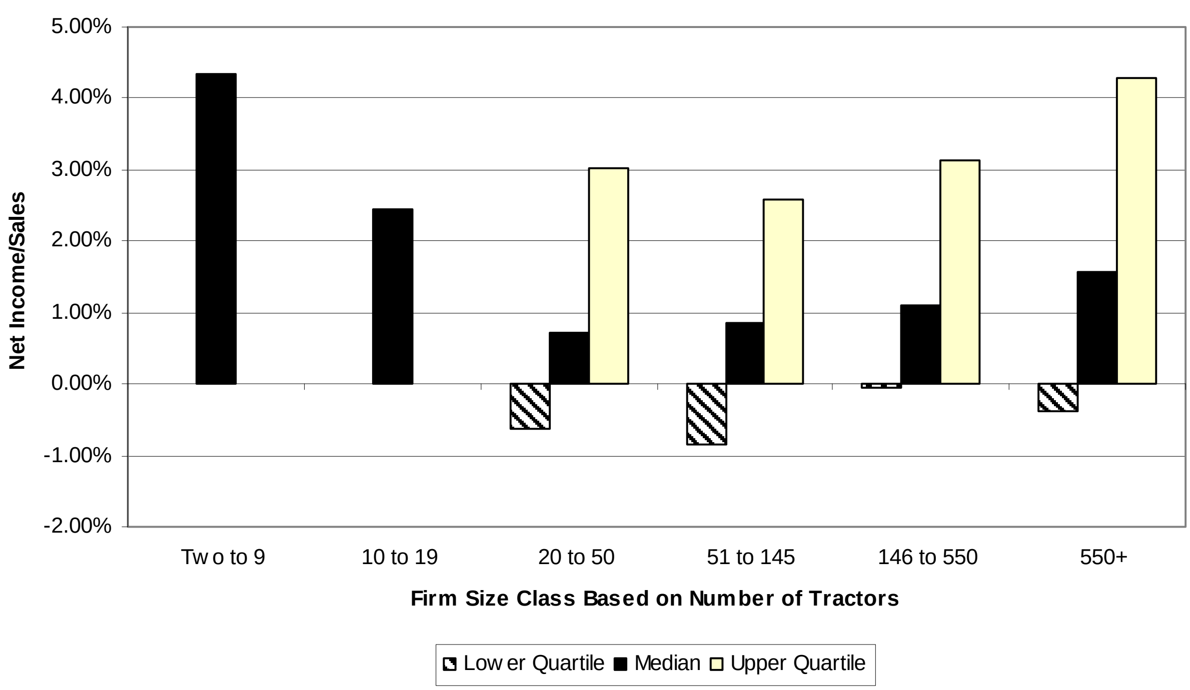
Exhibit 7-1 summarizes the baseline profitability of carriers in the various size categories. Note that Exhibit 7-1 (like many of the remaining exhibits in this chapter) does not address firms in the smallest size category (i.e., owner/operators with a single tractor) because the results for these entities require a slightly different interpretation than the results for other size categories and they are addressed separately in section 7-3.

The remainder of this chapter is divided into three sections. Section 7.1 provides an overview of the results of the impact analysis. Section 7.2 organizes the results by regulatory option. Section 7.3 organizes the results by different carrier size categories.

## 7.1 SUMMARY OF RESULTS

This chapter presents the results of a study of the financial impacts of Options 2, 3, and 4 relative to Option 1, under two assumptions about prices of trucking services: unchanged prices (representing the short run), and prices after industry-wide cost changes have been passed through to consumers. Relative to Option 1, all of the other options result in adverse financial impacts (reduced profits) on most carriers. The severity of the impacts is directly related to the magnitude of the drop in labor productivities considered for the three options. As another point of comparison, however, carrier profitability under each of the options is also shown under the state-of-the-world that existed before the 2003 rule came into effect. This state is referred to as the "Pre-2003 Situation." Comparing the impacts of the new options to this situation provides additional perspective and may be more realistic in some cases since it is unclear if all carriers have had enough time to adjust to the 2003 HOS rule.

**Exhibit 7-1**
**Baseline Profitability of Representative Carriers**



Option 2 (with a 0.1 percent drop in labor productivity), shows the least severe adverse impacts.[56] In the period before prices adjust, profitability as a share of revenue is projected to decrease by a tenth of one percent or less, relative to Option 1 These very minor impacts should be reduced slightly as prices adjust. Option 3 (with a 7.12 percent drop in labor productivity) has the most severe impacts on carriers, and could eliminate net income in the short term for some industry size categories. The impacts are less severe, however, when measured in terms of profitability as a share of operating revenue. The biggest impact of 2.6 percent is felt by the 20-50 size class before prices adjust. Option 4 (with a 4.61 drop in productivity) shows impacts that are in-between the two extremes (i.e., Option 2 and Option 3). These findings are consistent with the cost results presented in Chapter 6. (See Section 7.2 for further discussion of the results by option.)

The results, in terms of profit impacts relative to revenues under Option 2, seem to suggest very small impacts for firms across the wide range of size categories examined, including both large and small entities. The threshold for impacts considered to be of moderate size is generally taken to be one percent of revenues, and the average impacts of Option 2 fall far below that magnitude (specifically, one-tenth of one percent or less within all small entity groups). Also, it should also be noted that even though Option 2 would result in slightly lower profitability than Option 1, carriers would generally earn higher net revenues under Option 2 than they were under the pre-2003 rule, only a short time ago.

Variability in impacts within each size category, however, means that the possibility of larger impacts for some small entities are possible. The carriers that are currently taking advantage of the split break periods to an above-average degree, for example, will tend to lose more under the options that do not permit its use. Even for these carriers, however, the average impacts are likely to be well below 1 percent.

### 7.2 RESULTS BY OPTION

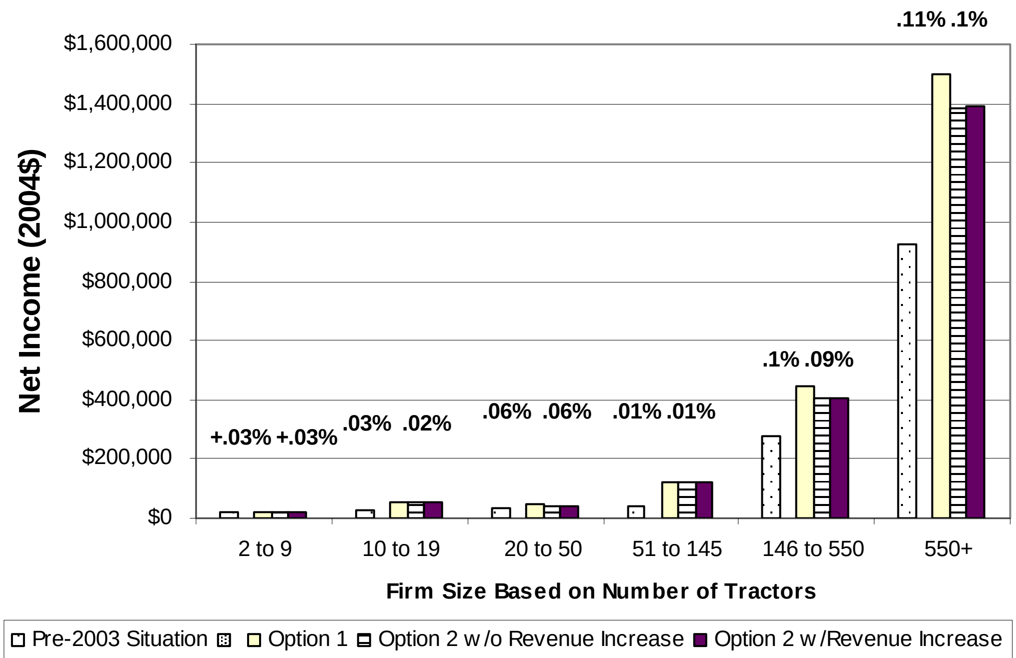
Option 2 adversely impacts the net income earned by carriers in almost every size category (with the exception being a very small improvement for the 2-9 category) as shown in Exhibit 7-2, although these impacts are very small in magnitude. Exhibits 7-2 through 7-4 show the impacts on each size category under two assumptions. "Without Revenue Increase" implies carriers bear the increased costs due to the rule change without being able to pass-through the cost increases to their customers through trucking rate hikes (i.e., zero pass-through). This scenario would be likely to hold only in the very short run. In the longer run, carriers are expected to be able to increase their rates in line with industry-wide increases in costs. This scenario is modeled as "With Revenue Increase" which assumes that the industry as a whole is able to pass through its average cost increase to its customers. These two extremes of the pass-through assumption were modeled in order to provide a range for the level of impacts associated with the new options as well as to distinguish between short- and long-run.

[56] The industry as a whole is expected to experience a smaller 0.042% drop in productivity under Option 2. The analysis presented in Chapter 6 found, however, that this impact would fall disproportionately on the TL for-hire sector that is the focus of this chapter. We have accounted for this circumstance by dividing the industry-wide drop in productivity by the share of VMT accounted for by the TL for-hire sector.

In addition to showing impacts on net income, the exhibits indicate the drop in profit as a percentage of operating revenue for each alternative relative to Option 1. Those relative changes are shown above each bar in all three exhibits.

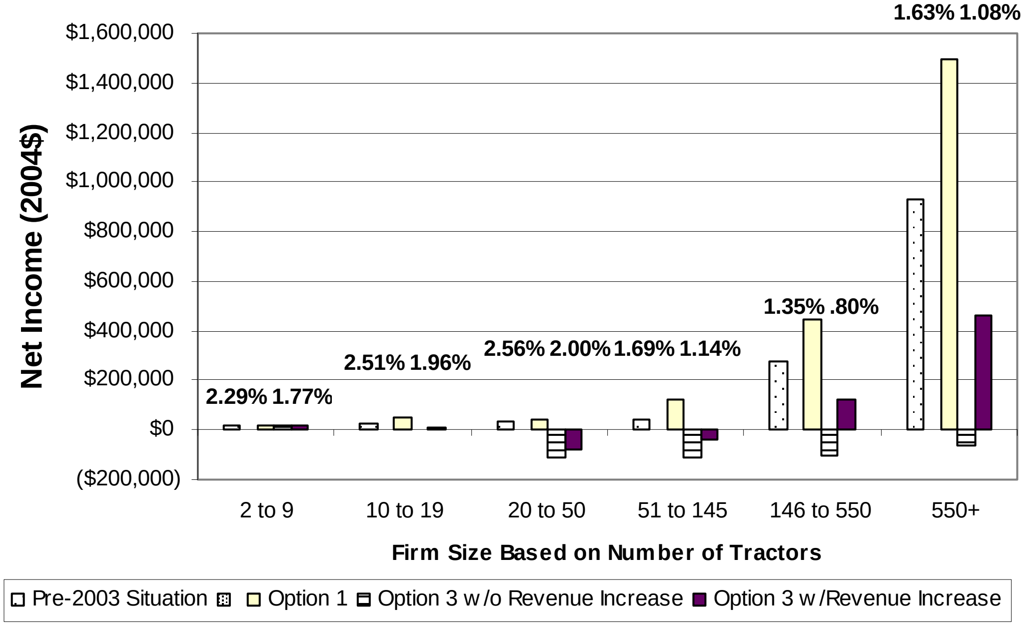
Exhibit 7-3 and Exhibit 7-4 show the impacts for different size categories for Options 3 and 4, respectively. Both options result in significantly lower net incomes than for Options 1 and 2 in all size categories.

**Exhibit 7-2: Option 2: Change in Median Firm Net Income Relative to Baseline (Reduction in profit relative to total revenue is indicated over the bars)***



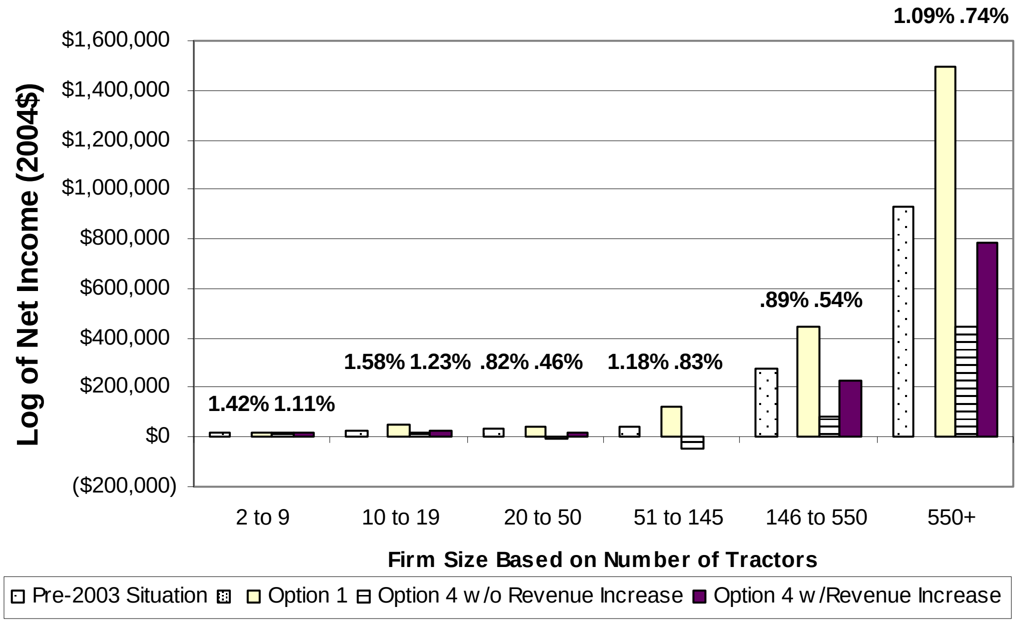

** Profit reduction calculated relative to Option 1 baseline.*

**Exhibit 7-3**
**Option 3: Change in Median Firm Net Income Relative to Baseline**
**(Reduction in profit relative to total revenue is indicated over the bars)***




** Profit reduction calculated relative to Option 1 baseline.*

**Exhibit 7-4**
**Option 4: Change in Median Firm Net Income Relative to Baseline**
**(Reduction in profit relative to total revenue is indicated over the bars)***




** Profit reduction calculated relative to Option 1 baseline.*

## 7.3 Differential Impacts on Small Carriers: Results by Size Categories

This section describes impacts on carriers in seven size categories. The discussion is divided into four parts: one for owner operators; one for firms with 2-9 tractors; one for firms with 10-19 tractors; and the last for the larger size categories.

As expected, the percentage changes in net income indicate that the impacts are less in the longer run when carriers can increase their revenue by passing the industry-wide average cost increases on to their customers.

Impacts on the profitability of certain firm sizes appear to be greater than the impacts on others. This pattern is closely tied to the differences in baseline profitability levels: those size categories with lower rates of profit in the baseline are naturally somewhat more vulnerable to a similar change in productivity.

### 7.3.1 Owner/Operators with One Tractor

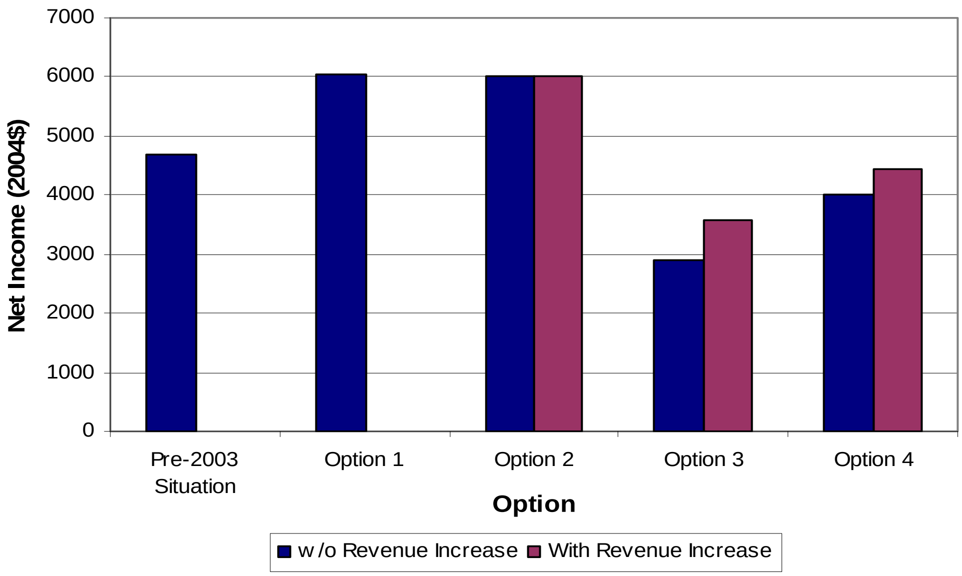
The smallest size category, one tractor, is examined in order to evaluate impacts on individual owner/operators. Exhibit 7-5 shows the change in net income for these owner/operators under each option. These impacts are presented relative to Option 1; the pre-2003 situation is shown as well.

Owner/operators with one tractor would earn virtually the same under Option 2 as Option 1, and less under the other two options. Net income is actually higher under Option 2 than in the pre-

2003 situation. Owner-operators that did not have sufficient time to adjust to the 2003 rule may therefore experience an improvement in their situations.

The "net income" estimated in this study for owner/operators is slightly different in meaning than that for firms in other size categories due to treatment of wages. For owner/operators, net income is the same as take-home pay (analogous to wages). The owner/operator "takes home" any residual after paying all other expenses. In contrast, the net income of larger firms subtracts out wages along with other expenses. Due to this difference, the net income calculated for owner/operators is not directly comparable to that calculated for other firm sizes, and it tends to be higher when stated as a percent of revenue.

**Exhibit 7-5: Change in Net Income for Owner Operators (One Tractor/Trailer)**




* Net income for owner operators includes wages. See text for details.

### 7.3.2 Firms with 2-9 Tractors

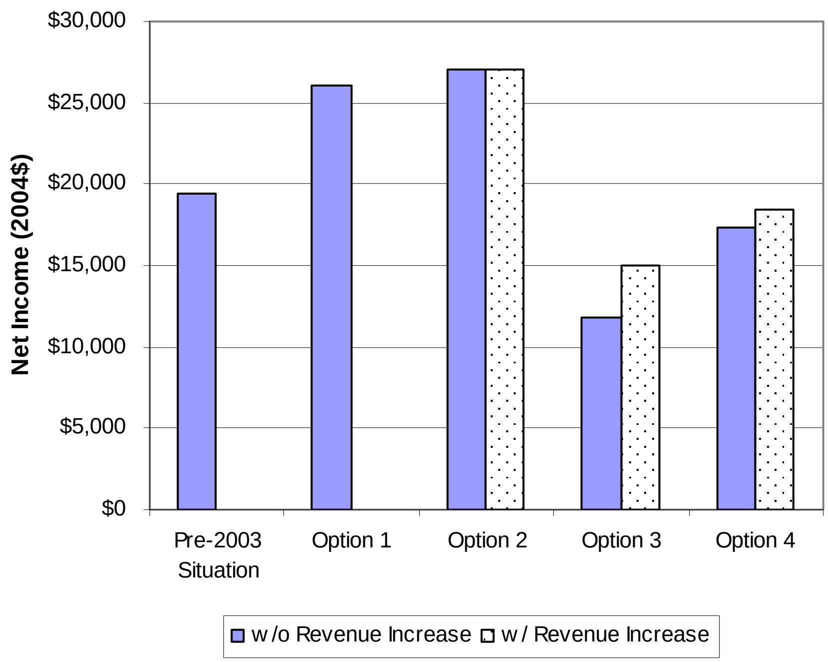
Firms operating 2-9 tractors and others toward the smaller end of the size distribution may have less flexibility to respond to a change in the HOS rules. Whereas larger firms can hire or lay off drivers in order to optimize their operations relative to any of the options, firms with 2-9 tractors are too small to do this in optimal fashion, at least in the near term.[57] As discussed above, firms must hire additional drivers in order to maintain their current business under Options 3 and 4. Firms in the 2-9 tractor category, however, do not have enough current business to justify hiring another full-time driver. They would, optimally, hire a fraction of a driver in response to the new

[57] To a lesser extent this also is true for firms in the 10-19 tractor size category. Firms with 10-19 tractors have enough flexibility, however, that their impacts are similar to (but smaller than) those of firms in larger size categories.

options. Assuming this is not possible, these firms must instead sacrifice some of their business, at least in the near term.[58]

As shown in Exhibit 7-6, carriers in this size category are expected to gain to an insignificant degree under Option 2, most likely due to slight changes in driver wages. They would be adversely impacted under Options 3 and 4 relative to Option 1, because of their inability to meet existing orders and the loss of the corresponding revenues. Near-term impacts ("without revenue increase" – i.e., before prices for trucking services adjust to the cost increases) are higher than the long-run impacts ("with revenue increase").

**Exhibit 7-6: Net Income Per Firm: 2-9 Tractors**

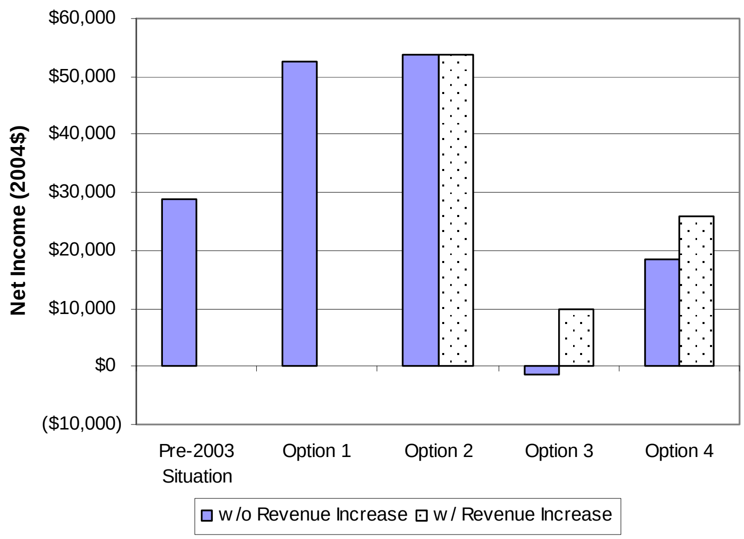



## Firms with 10-19 Tractors

Impacts for the 10-19 tractor size category differ somewhat from the 2-9 size category. Again, there is almost no impact under Option 2. Due to their lower baseline profitability (as shown in Exhibit 7-1 above), the percentage drop in net income for this size category under Options 3 and 4 appears to be greater than the 2-9 size category.

[58] In the longer term, firms should be able to adjust their operations to a greater extent in order to fill capacity, so the impacts on these firms should tend to diminish over time.

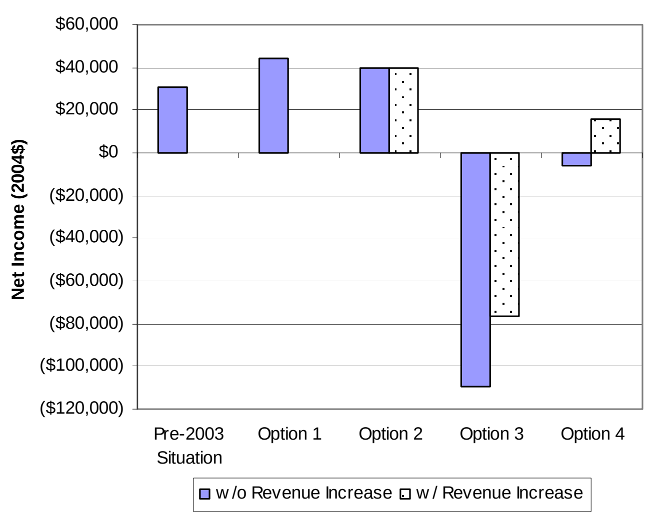
**Exhibit 7-7: Net Income Per Firm: 10-19 Tractors**



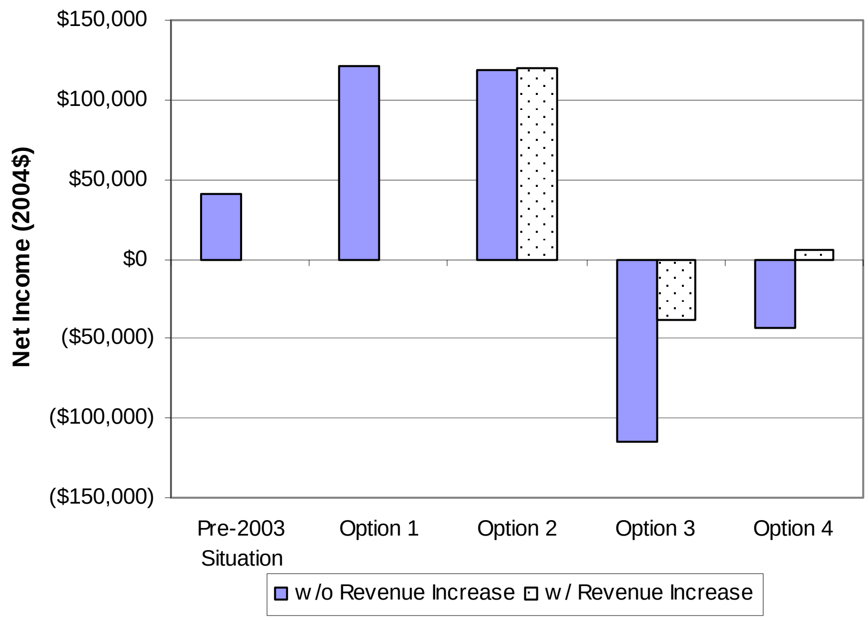

### 7.3.3 Larger Size Categories

Exhibits 7-8 through 7-11 summarize the expected change in profitability for firms in the remaining four size categories. These impacts appear less severe if carriers are assumed to have an opportunity to increase their rates to offset the higher costs of the new rules. Moreover, though the carriers are generally less well off under Option 2 than under Option 1 (except carriers in the 51-145 size category, where they are virtually the same), many are likely to earn higher net revenues than they were under the pre-2003 rule.

**Exhibit 7-8: Net Income Per Firm: 20-50 Tractors**



## Exhibit 7-9: Net Income Per Firm: 51-145 Tractors




## Exhibit 7-10: Net Income Per Firm: 146-550 Tractors

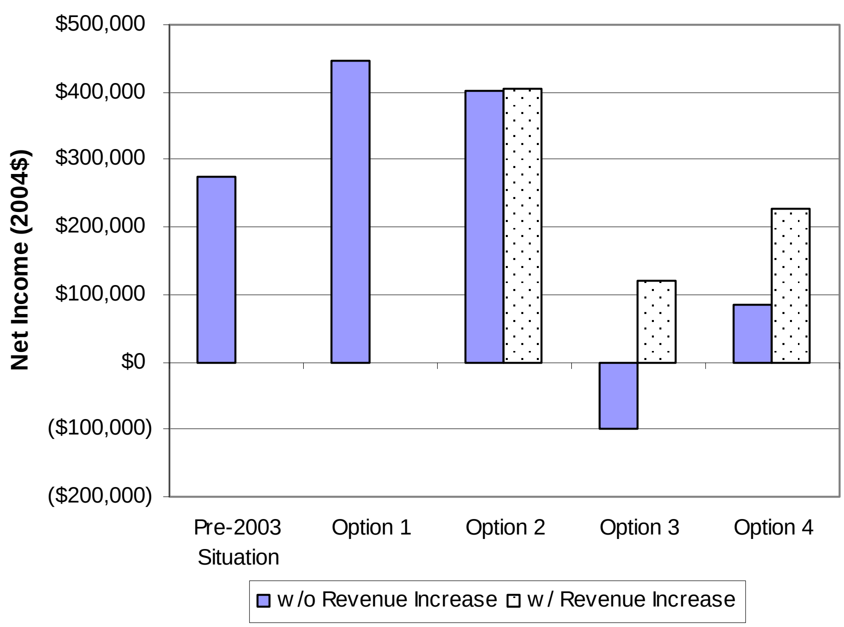
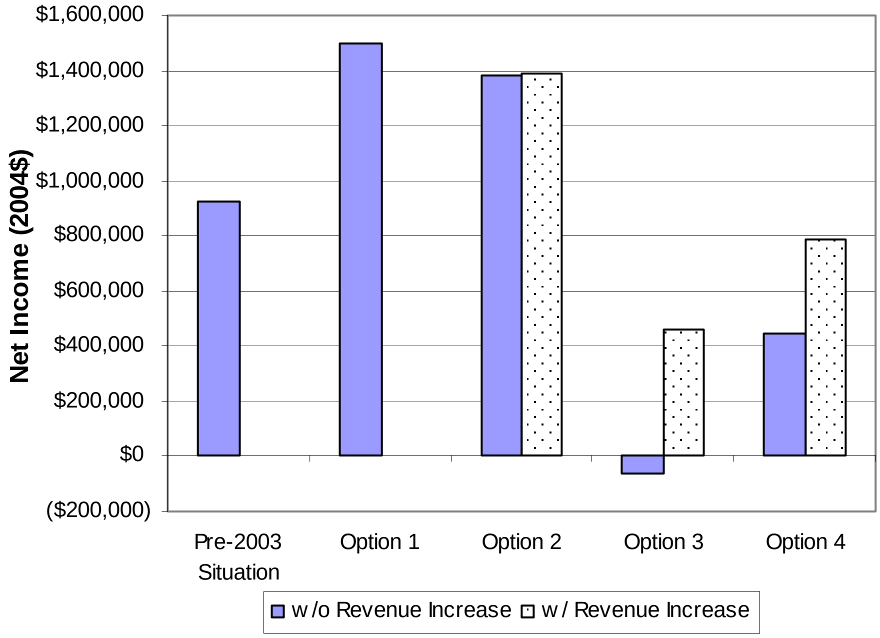


**Exhibit 7-11: Net Income Per Firm: 550+ Tractors**




## 7.4 CONCLUSIONS AND FACTUAL BASIS FOR CERTIFICATION

Earlier in this chapter, FMCSA presented estimates which indicate that, as a percentage of total revenues, the financial impact of Option 2 (today's rule) is exceedingly minor across the spectrum of all small firms included in the analysis. Specifically, translating productivity impacts into a reduction in net income of the median firm from each size category, FMCSA found that under Option 2, reductions in net income as a percent of total revenues averaged one-tenth of one percent or less for small firms in all size categories of small entities. In its small business impact analyses, FMCSA has traditionally used one percent of revenues as the threshold for "significant" financial impacts to trucking firms. Since the average impact of Option 2 is only one-tenth of that figure, FMCSA considers the financial effect of today's rule to be minor for the median firm in each size category. Additionally, small entities in all size categories are expected to have higher net income under Option 2 than under the pre-2003 environment.

Adverse financial impacts will vary by individual firm, and there might be some firms in each size category that make extensive use of the split sleeper berth provision. To determine whether these firms could experience significant adverse financial impacts as a result of today's rule, FMCSA has combined its estimates of the total impact of Option 2 as a percentage of revenues with data on the distribution of the use of the sleeper-berth exception among owner-operators. FMCSA has focused on the use of the sleeper-berth exception because this provision is the only area in which Option 2 differs from the baseline (the 2003 rule) in a way that could cause adverse impacts. Thus, the total cost of Option 2 is likely to fall on the carriers that make use of the opportunity to split rest periods. Furthermore, the distribution of these costs are likely to parallel the distribution of the use of the provision: carriers whose drivers use the provision twice as often as the industry average, for example, can be assumed to bear twice the industry average impacts. If a given carrier has a large number of drivers, it is likely that some will use the provisions more than average and others will use it less, leading to an average impact for larger carriers that is relatively close to the industry average. This phenomenon would not apply to owner-operators, however, because they do not employ many drivers whose average behavior can be assumed to resemble the average across the industry. For this reason, FMCSA has used data relating specifically to this relatively more vulnerable sector in order to measure the degree of variability in the impacts of Option 2.

A summary of the data from an Owner-Operator Independent Drivers Association (OOIDA) survey is shown in Exhibit 7-12. Most respondents did not use the provision at all in the month referenced in the survey (June 2004), and almost 80 percent used it five times or less. On average, it was used just under four times in the month. Some respondents, however, reported using it extensively – up to 25 or even 30 times in the month. Those using the provision the most are assumed to bear the most disproportionate impacts if it is restricted. For example, those splitting their rest periods every day of the month use the provision 30/3.96 or 7.57 times the industry-wide average, and might be expected to bear 7.57 times the industry-wide average impacts. Since it is not possible to use the provision more than 30 times in a 30-day month, it is reasonable to assume that the impacts on any one carrier will not be more than 7.57 times the average.

As noted earlier in this chapter, the industry-wide average impact of Option 2 was 0.042 percent of revenues. Because this impact was expected to fall much more on the 41.7 percent of the industry's operations that consist of for-hire truckload carriage, FMCSA conservatively assumes that the average impact on for-hire truckload carriers is 0.042%/41.7% or just over 0.1 percent of revenues. The right-hand column of Exhibit 7-12 shows the impacts of Option 2 across small carriers if these impacts are distributed in proportion to their baseline use of the split sleeper berth break provision: more than 90 percent would have cost increases of 0.35 percent or less, less than 5 percent would have costs increases of 0.6 to 0.7 percent, and only one percent would bear the highest costs of 0.76 percent of revenues. It is likely that even these impacts would be reduced if more than one month were considered, because some of the operators with the highest use in one month could show more typical patterns in other months.

**Exhibit 7-12: Owner-Operator Costs by Intensity of Sleeper-Berth Use**

| Times Split Sleeper Berth Provision was Used in June | Number of Owner Operators | Percentage of Responses | Total Days the Provision was used | Multiple of Average Use | Estimated Impacts: Cost as a Percentage of Revenues |
|---|---|---|---|---|---|
| 0 | 685 | 55% | 0 | 0.00 | 0.00% |
| 1-5 | 277 | 22% | 758 | 0.69 | 0.07% |
| 6-10 | 108 | 9% | 867 | 2.03 | 0.20% |
| 11-15 | 58 | 5% | 790 | 3.44 | 0.35% |
| 16-20 | 60 | 5% | 1,151 | 4.84 | 0.49% |
| 21-25 | 36 | 3% | 857 | 6.01 | 0.61% |
| 26-29 | 6 | 0.5% | 162 | 6.82 | 0.69% |
| 30 | 11 | 1% | 330 | 7.57 | 0.76% |
| All | 1,241 | 100% | 4,915 | 1.00 | 0.10% |
| | | | Average = 3.96 | | |

**Source: Survey of OOIDA members and ICF analysis**

Because only a very small fraction of the most affected small businesses would bear the highest costs, and because even those impacts are below the threshold of 1 percent of revenues, FMCSA can reasonably conclude that Option 2 would not have a significant impact on a substantial number of small entities.

## APPENDIX (I) INDUSTRY DATA

### (I).1 REGULARITY IN TL SERVICE

The percentage of TL service that is regular in character was estimated from three sources: conversations with Schneider staff; interviews conducted by George Edwards with eight TL carriers[59]; and the field survey conducted.

**Schneider conversations:** These suggest that something better than 50 percent of that firm's operations are regular.

**Edwards interviews:** The data from interviews with eight TL companies, weighted by company size (number of tractors), show 33 percent of truck-miles in regular operations.

**Field survey:** We considered a driver to be in regular operation if he had three or more weekends at home in a month. On that basis, 41 percent of apparently compliant 60 drivers were in regular operations. We further tested this by looking at times for starting and ending daily work for this group. This test showed a very strong tendency for drivers from the regular set to start and finish at the same time each day—further confirmation of regular operation. Start and finish times for the random drivers showed no consistent patterns at all—a clear sign of non-regular operation.

The following table shows our three data points for percentage of regular operations in TL service.

**Exhibit (I)-1**
**Regularity in Truckload Service**

| | Regular Percentage |
|---|---|
| **Schneider** | >50 |
| **Eight TL Firms** | 33 |
| **Field Survey** | 41 |

On the basis of these findings, we have used 40 percent for our estimate of regular TL service. There is some reason to think this estimate is low. Our criterion for regular drivers in the field survey may be too narrow. It is undoubtedly the case that some drivers have regular runs that keep them out for one to three weeks. Further, the field survey and the Edwards interviews reflect relatively small TL concerns (by design in the case of the interviews). Most TL companies try to get as much regular business as they can, and there is every reason to believe that the largest companies are the most successful in this regard. Their size and reach enable them to accommodate the demands of very large manufacturers and distributors.

[59] George Edwards is one of our team of industry experts.

[60] We considered drivers as non-compliant if they recorded more than 11 hours of driving or 14 hours on duty in a tour. These anomalies could reflect errors in log keeping or other record keeping.

## (I).2 INDUSTRY EXPERTS

The following individuals comprise the informal team of industry experts with whom we frequently consulted on many aspects of trucking-industry operations. With some of these people, we met face to face on two occasions for discussion of industry practice. We consulted them frequently by telephone and e-mail.

Michael Belzer, Wayne State University
Stephen Burks, University of Minnesota
George Edwards, trucking consultant
John Nienow, Schneider National
Donald Osterberg, Schneider National
Daniel Pierce, Schneider National
John Siebert, Owner Operator Independent Driver Association

Professors Belzer and Burks, and Mr. Edwards were paid consultants to ICF. We contracted for the services of Professors Belzer and Burks through Sound Science, Inc.

## (I).3 ESTIMATION OF VEHICLE MILES OF TRUCKS FROM 10,000 TO 26,000 POUNDS WITHIN 150 AIR MILES OF THEIR HOME BASES.

In order to estimate the effects of a rule change for trucks in this size class, it is necessary to estimate truck-miles of operations of these vehicles within 150 air-miles of their home bases. Base is defined as the place where the truck is parked when not in service and from which the driver starts at the beginning of his work day and to which he returns at the end of it. It could be, for example, a factory, warehouse, office, trucking terminal, or residence. This estimate is based on the Vehicle Inventory and Use Survey (VIUS) in the 2002 Economic Census. Exhibit (I)-2 below shows the distribution of VMT of medium and light-heavy trucks across the operating-range intervals specified in the VIUS.[61] Operating range is a distance from home base beyond which the driver does not usually go in his normal operating pattern.

**Exhibit (I)-2**
**VMT (millions) in Primary Range of Operation**

| Range (miles) | VMT | Percent |
|---|---|---|
| 0-50 | 19,581 | 62% |
| 51-100 | 6,416 | 20% |
| 101-200 | 2,199 | 7% |
| 201-500 | 1,837 | 6% |
| > 500 | 1,298 | 4% |
| Total | 31,331 | 100% |

Source: 2002 VIUS, Table 6, p. 47.

In order to go from these numbers to our VMT estimate, two further steps are required. Since the VIUS data do not directly give us mileage for an operating range of less than 150 miles, we must

[61] Census definitions: Medium trucks are from 10,001 to 19,500 pounds, and light-heavy trucks are from 19,500 to 26,000 pounds.

assign a fraction to the mileage in the 101-200 range to the 101-150 range. Also, the data in Exhibit (I)-2 understate total mileage because not all respondents answered the range-of-operation question.

Seventy-five percent of the VMT in the 101-200 range are in the 101-150 range. This is because the operations of these vehicles are heavily concentrated in the shorter ranges. As the operating range is extended past 100 miles, a smaller share of VMT is added with each increment in operating range. As the table shows, 62 percent of VMT are inside 50 miles; going out to 100 miles adds another 20 percent; and the 100-mile extension to 200 miles adds only another 7 percent. Therefore, it is reasonable to assume that the preponderance of the VMT in the 101-200 band are inside 150 miles from home base. In this context, we believe that 75 percent of these VMT can be prudently assigned to the 101-150 range. On this basis, the data in Exhibit (I)-2 yield an estimate of 27,646 million VMT within 150 air miles from home base for trucks in this size range.

This estimate must be adjusted upward to allow for the respondents who did not answer the range-of-operation question. For this purpose, we assume that the distribution of mileage over the operating range is the same for those who did not report it as those who did. Total mileage attributed to those who did not report range of operation is 6,085 million.[62] Total mileage for those who did report is 31,331 million. Since 6,085/31,331 = 0.194, we adjust upwards by this factor; 1.194 x 27,646 = 33,015. We may round this to 33.0 billion VMT.

One more difficulty with these data must be addressed. The entries in Table 6 are under the heading, Primary Range of Operation. “Primary” refers to the range in which a respondent’s vehicle runs most of its miles. On the survey form, the respondent enters estimated VMT for each operating range; if the form shows 60 percent of a vehicle’s VMT in the 101-200 range, *all* of its VMT is assigned to that range in Table 6. Therefore, some of the VMT shown in Table 6 in the 101-200 range actually was in some other operating range, whether shorter or longer. To the extent that some of the actual VMT was in shorter ranges (<101), we are not concerned; our goal is to estimate all VMT in ranges of less than 150 miles. To the extent that VMT in the 101-200 range in Table 6 was actually in ranges greater than 200 miles, we do have a concern.

The question is really whether the VMT distribution over the ranges by the “primary” method is significantly different from the distribution that results from assigning a respondent’s VMT according to what is actually shown on the form. Table 8 of VIUS shows mileage in operating ranges as actually reported but only for all trucks and all trucks except light trucks. We can, however, compare the mileage distribution according to the “primary” method from Table 6 with the reported distribution in Table 8 for all trucks except light trucks. These distributions are quite different from that for the 10,000-26,000 pound trucks we are studying, because it includes the heaviest trucks whose use entails far more long-range operation than does any other class of truck. Nonetheless, if the distributions for all-except-light trucks are similar, we have reason to

[62] The unreported mileage is in two categories. not reported and not applicable. In the former case, respondents simply did not fill out the range-of-operation part of the survey form but reported total mileage. In the latter case, respondents owned vehicles for less than a full year; their total mileage was adjusted upward to allow for this but was not distributed over the operating ranges. VMT not reported was 6,013 million and not applicable was 72 million.

accept the estimates obtained from the data on primary ranges. This comparison is shown below in Exhibit (I)-3.

**Exhibit (I)-3**
**Distribution of VMT (millions) over Operating Ranges for All-except-light Trucks**

| Range (miles) | Primary VMT | Percent | Actual VMT | Percent |
|---|---|---|---|---|
| 0-50 | 41018 | 35% | 38231 | 33% |
| 51-100 | 19499 | 17% | 22238 | 19% |
| 101-200 | 12133 | 10% | 14286 | 12% |
| 201-500 | 17842 | 15% | 17539 | 15% |
| > 500 | 27075 | 23% | 25016 | 21% |
| Total | 117567 | 100% | 117310 | 100% |

We see that the percentages across the operating ranges are very close to the same. Assignment of VMT to the ranges on the basis of the "primary" method gives us no reason to set aside our estimate of 33 billion VMT inside 150 air miles from home base for 10,000-26,000 pound trucks.

### (I).4 INTENSITY OF EFFORT—REGULAR VS. RANDOM OPERATION

In the following table, based on field survey data, we compare intensity of effort as between regular and random operation. ICF has defined an intense-effort driver as one who uses the 11th hour at least twice in a month and who works 65 hours in seven days at least once in a month. We present data for both compliant and non-compliant drivers and for all drivers in the survey.(We label as non-compliant those drivers in the field survey who logged more than 11 driving or 14 work hours in a tour of duty. Of course, these might reflect some errors in log entries.)

**Exhibit (I)-4**
**Relative Intensity of Effort—Regular vs. Random**
**Percentage of Intense-effort Drivers**

| | Regular | Random | Combined |
|---|---|---|---|
| **Compliant** | **19%** | **39%** | **31%** |
| **Non-compliant** | **68%** | **88%** | **84%** |
| **Combined** | **31%** | **65%** | **55%** |

NOTE: These data represent for-hire OTR truckload drivers.

We see that intensity of effort is greatest among random drivers and among non-compliant drivers. Of random drivers, 65 percent show intense effort; among all non-compliant drivers, 84.0 percent show intense effort. We note that the relatively high intensity of effort shown in Exhibit (I)-4 for random drivers is heavily influenced by the definitions of regular operation and intense effort that we used with the field survey data. We defined regular drivers as those who had three or more instances in a month of two consecutive days off, i.e., drivers who do not work on weekends. Relatively few of such drivers will work 65 hours in a seven-day period. Recall that, when we measured intensity of effort by hours worked in a tour of duty, there was little difference between random and regular drivers (Exhibit 2-3 in section 2.1.4)

## (I).5 SPLIT SLEEPER PERIODS—REGULAR VS. RANDOM

The following table, based on data from the field survey, compares incidence of splitting for regular and random drivers.

**Exhibit (I)-5**
**Percentage of Drivers Splitting**

| | Regular | Random |
|---|---|---|
| Drivers Logging at Least One Break as Split | 36% | 51% |
| Drivers Actually Splitting at Least Once | 29% | 35% |
| Tours of duty with actual splitting | 3.5% | 5.9% |

NOTE: These data represent for-hire OTR truckload drivers.

Periods "logged as split" means hours were entered for split sleeper periods. In many cases, however, ten or more hours were entered in "split" periods. "Actual" splitting means two sleeper periods added to at least ten hours and neither was less than two hours or more than ten.

Once we focus on actual splitting, we see that neither group splits very often, and the regular drivers are substantially less likely to split than random drivers.

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## APPENDIX (II) DETAILS OF MODELING OF CARRIER OPERATIONS

### Definition of Regions

As one of the user-defined assumptions, the model can simulate one or more of four continental U.S. regions: Northeast, Midwest, West, and South. The Northeast region includes Connecticut, Delaware, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont. The Midwest region includes Illinois, Indiana, and Ohio. The West region includes Arizona, Arkansas, California, Colorado, Iowa, Idaho, Kansas, Louisiana, Minnesota, Missouri, Montana, Nebraska, New Mexico, Nevada, North Dakota, Oklahoma, Oregon, South Dakota, Texas, Utah, Washington, and Wyoming. The rest of the states constitute the South region.

### Default Assumptions

In addition to the assumptions that can be revised by the user, the model has a number of default assumptions, detailed here:

- *Loading and Unloading Time* The time required for loading and unloading the vehicle is based on a random draw from a normal distribution with a mean of 2 hours and a standard deviation of 30 minutes. Further, we have assumed for computational ease a minimum loading and unloading time of 30 minutes, with the concurrence of industry expert opinion for reasonableness.

- *Pick-up Day of Week* The distribution of the day of the week for shipment pick-ups is based on a report by Reebie Associates[63], which determined the following patterns from data available from truckload carriers:

**Exhibit (II)-1: Day of Week Patterns**

| Day of Week | Percentage |
|---|---|
| Sunday | 0.8% |
| Monday | 17.8% |
| Tuesday | 19.7% |
| Wednesday | 19.9% |
| Thursday | 19.0% |
| Friday | 19.5% |
| Saturday | 3.3% |

Exhibit (II)-1 shows that pick-up days are basically evenly distributed for the weekdays while the weekends are rarely used. The simulation of the pick-up day for a given shipment in the model is based on the percentages shown above. However, we have limited the alternatives so that the available possibilities for the next shipment pick-up are the same day as the just-completed drop-off and the two days immediately subsequent. For example, if the truck has arrived on Tuesday,

[63] "Day-of-Week Motor Carrier Demand Patterns," Reebie Associates, June 12, 2002.

the pick-up day choices for the next shipment would be based on the relative distributions for Tuesday, Wednesday, and Thursday.

- *Delivery Day of Week* The scheduled delivery day of the week depends on the pick-up day of week and the travel time required to the delivery destination. The model calculates a simplified transit time from the origin to the destination as equal to the distance between the origin and destination divided by the average driving speed (default of 50 mph), and then doubled to allow for non-driving time (for breaks, etc.). Effectively, this makes trips feasible if the CMV operator spends at least 50 percent of the time after pick-up driving.

- *Pick-up and Delivery Windows* The pick-up and delivery windows represent the interval of time in which a pick-up or interval needs to be made. Based on research and input from industry experts, they are assumed to have the distributions shown in Exhibit (II)-2:

Exhibit (II)-**2**
**Distribution of Pick-up and Delivery Windows**

| Window size | Pick-up Window | Delivery Window |
|---|---|---|
| 15 or 30 Minutes | 11% | 44% |
| AM or PM | 37% | 33% |
| Whole Day | 53% | 22% |

If the whole day is noted as the pick-up/delivery window, the CMV operator is able to pick-up/drop off any time during the day. Similarly, we assumed that the AM window is from 12 midnight to 12 noon while the PM window is from 12 noon to 12 midnight. For the shorter 15 minute and 30 minute windows, we assigned the distribution of pick-up/delivery windows as suggested by the industry experts following the distribution of all actual pick-up and delivery times. The pick-up and delivery window distributions for the 15 and 30 minute windows are shown in Exhibits (II)-3 and (II)-4. Within each of these ranges, the actual window was randomly assigned (using a uniform distribution) to a time increment commencing within the range.

Exhibit (II)-**3**
**Distribution of Pick-up Hours for 15 or 30 Minute Windows**

| Pick-up Hour | % of Shipments |
|---|---|
| 22:00-10:00 | 60% |
| 10:00-14:00 | 30% |
| 14:00-22:00 | 10% |

Exhibit (II)-**4**
**Distribution of Delivery Hours for 15 or 30 Minute Windows**

| Delivery Hour | % of Shipments |
|---|---|
| 05:00-08:00 | 40% |
| 08:00-14:00 | 40% |
| 14:00-21:00 | 10% |
| 21:00-05:00 | 10% |

**Model Operation Note**

In a few cases, none of the 20 origin-destination pairs that the CMV operator faces are feasible. For example, if a CMV operator arrives at the destination on late Friday, then all 20 pairs presented to the operator may be infeasible since the model draws very few Saturday and Sunday pick-ups (and may pick all 20 pickups for earlier in the day on Friday than the driver is available). In such cases where no origin-destination pair is feasible, the model allows the driver to have an extra day of pick-up (Monday) so the driver can choose from a feasible set of choices. Then, the model simulates all 20 O-D pairs instead of only the top seven, to ensure that the CMV operator chooses the shipment with the highest utility.

**Order Sets**

The process of obtaining a representative sample of the US truck transportation industry's movements began by obtaining data sets containing the total tons shipped to and from every county in the country, sorted by FIPS code[64]. It was decided to base the sample on the total tons shipped to and from each county to best represent the number of truckload moves. The shipments to and from each county were combined to create a table relating each county to the total tons shipped associated with it. This data set provided 3,141 data points from which to create a sample. First, a sample size of 1,000 was established, to speed model computation time and assuming that quantity to be more than sufficient to represent industry movements for the purposes of the model. Next, those counties and areas located outside the lower 48 states were removed from the potential sample, as their geographic circumstances would not permit modeling within this framework. This step reduced the number of FIPS codes used as potential data points to 3,109. Then, counties were sorted by total tonnage, and the 194 counties whose movements made up 60 percent of total goods shipped were placed in the sample. The remaining 2,915 counties were assigned random values between 0 and 1, and those with the 806 largest random numbers were included in the sample to complete the set of 1,000.

Treating the sample set as a closed system, statistical software was then used to calculate the probability of a shipment going from each FIPS origin to each separate FIPS destination, ignoring the probabilities associated with the FIPS areas outside the sample. Because the 2,915 smaller counties were now under-represented in the sample, an imbalance was present in the O-D probabilities. In order to correct this imbalance, the proportion of total tonnage of low-volume counties in the data set relative to the tonnage of those low-volume counties used in the sample

[64] FIPS codes generally represent counties, parishes or districts. The term county is used interchangeably herein to also represent FIPS code areas, parishes and districts.

was calculated, which was roughly equal to 3.76. The origin-destination probabilities in cases where the destination was a low-volume county were then multiplied by that proportion.[65] This step effectively made the low-volume counties that were randomly selected for the sample stand in for all low-volume counties in the data set.

After this rebalancing of the sample's representation, the sum of the destination county probabilities for each individual origin county did not precisely equal one. In order to recalibrate the probabilities to achieve a workable model, each origin-destination combination's initial value was divided by the initial sum of the origin county's values. These new probability values were then summed to result in a total probability for each origin county of one.

**Utility Function**

The specific formulation and assumptions for the utility function are as follows:

Total Utility = Revenue - Cost – AwayFromHome Penalty + HOSStatusPremium

*where*

Revenue = Fixed shipment revenue + RevenueMiles from shipment pick-up to shipment drop-off * Revenue/mile) + ServicePremium revenue

*where*

Fixed shipment revenue = $120
RevenueMiles = Miles from shipment pick-up to shipment drop-off
Revenue/mile = $1.18
ServicePremium revenue = $25 per pick-up or drop-off with a15-minute or 30-minute time window

*and*

Cost = (OperatingCost/mile * VehicleMiles) + (Cost/clock-hour * ClockHours)

*where*

OperatingCost/mile = $1.13/mile for employee drivers paid per mile
VehicleMiles = Miles from previous drop-off to next destination drop-off (i.e., includes "deadhead" miles to shipment's pick-up)
Cost/clock-hour = $5.40/hour for employee drivers paid per mile
ClockHours = Total hours (duty and non-duty) from previous drop-off to next destination drop-off (i.e., includes "deadhead" time to shipment's pick-up time)

*and*

[65] Shipments to high-volume counties did not need adjustment as they were fully represented in the sample.

AwayFromHome Penalty = $V * ( max (0 , 1 - ( (DaysAway/W)^X * (DestDistAway/Y)^Z ) )

*where*

V = $10.00
W = 14 days
X = 2 (exponential parameter for time away from home)
Y = 500 miles
Z = 1.25 (exponential parameter for destination's distance away from home)

*and*

HOSStatusPremium = HoursBeforeRestart * Net revenue per duty hour

*where*

HoursBeforeRestart = Expected hours drivers will have remaining in 70-hour HOS work period before the 34 or 58 hour "restart" rest period

Net revenue per duty hour = $2.00 (based on expert opinion derived from revenue data presented in the *Blue Book*).

**Algorithms**

The details of the algorithms used to carry out some of the specific model components. are detailed below:

***Destination Algorithm***

The shipments' origins and destinations are based on recent empirical data regarding the actual probabilities of commercial truck movement from county to county in the continental United States. As explained in the order sets section (3.2.3), the available data provides the probabilities of shipment movements among the representative counties. Thus, the destination county is drawn based on the distribution of shipment movements from the origin county to potential destination counties. Specifically, when the destination algorithm is initiated, the model generates a random number between 0 and 1 and the model sequentially adds up each of the individual shipment probabilities associated with the origin county to potential destination counties until the cumulative sum is greater than the randomly generated number. Once the cumulative sum exceeds the randomly generated number, the model chooses the particular destination county that marginally increases the cumulative sum to be greater than the randomly generated number as one of the 20 origin-destination pairs.

***Load Choice Algorithm***

As explained in the operation section of Chapter 3 (3.2.2), the model simulates the top seven origin-destination pairs among the 20 pairs. The choice algorithm allows the user to see actual behavioral pattern of the driver in each of 15 or 30 minute time slots as the vehicle hypothetically would "move" from the origin terminal to the destination terminal. The algorithm also ensures the driver complies with all of the HOS regulations.

The algorithm starts each time increment with the decision of whether to rest or not. The CMV operator always decides to rest upon reaching the limit on driving hours or duty hours per day or the limit on cumulative duty hours in the last 8 days.

When the CMV operator decides not to take a rest, it has to decide whether to drive, load, unload, or just wait. The CMV operator waits[66] if it has driven four consecutive hours and still has more than one hour of driving left until the destination. If it has not reached the limit on driving hours and has not arrived at the destination, it chooses to drive. Once it arrives at the destination and is not resting, it either unloads or waits. To wait is counted as duty time, even though the truck is not moving, since the CMV operator is not fulfilling the HOS criteria for rest time. In these cases, the driver waits until it is within the delivery window and then unloads. Similarly, when it arrives at the pick-up terminal and is not resting, it waits until the time is within the pick-up time window and then loads the shipment.

The decision to drive, load, or unload is overridden when the CMV operator reaches the limit on the cumulative duty hours in the last 8 days. Then, the CMV operator automatically rests until its restart rest hours are met, or until the last 8 days included less than 70 hours on duty.

***Schedule Algorithm***

The schedule algorithm includes all the decision-making procedures within the choice algorithm. The schedule algorithm writes the selected origin-destination pair to the output table.

***Feasibility Algorithm***

In order to reduce the computing time for the model, we simulate seven origin-destination pairs among the 20 pairs that the CMV operator is presented with. The feasibility algorithm screened out the 13 pairs that would lead to the lowest utility. The algorithm calculates the travel time it takes to get to each pick-up terminal. Then it compares the travel time with the pick-up time and pick-up window of each origin-destination pair to check feasibility. Because the CMV operator is constrained by the limits on driving hours per day, a 4 hour drive to the next destination may take more than 4 hours. For example, it takes only 4 hours if the operator has at least 4 hours left on its daily limit on driving hours, but it would take 14 hours if the operator already had reached the limit on the driving hours per day and has to rest for 10 hours. Thus, the feasibility algorithm eliminates infeasible O-D pairs.

***Longer Restart Rest Period Algorithm***

When the CMV operator reaches the limit on cumulative duty hours in the last 8 days, the operator takes a restart rest of the required minimum hours (see user-defined inputs). This rest also re-set the cumulative count toward the limits. In other words, if the cumulative driving hours are at 5 hours, taking the restart rest hours re-sets the cumulative driving hours to 0 hours. In actuality, many commercial truck drivers take longer restart periods than are actually required, presumably in order to start their next working period in the morning or at a convenient or

[66] Effectively, this represents the driver taking a break without fulfilling criteria for HOS “rest”, and thus counts as duty time but not driving time.

accustomed time. Therefore, the model reflects the longer restart rests by imposing the following pattern of restart rests:

Long – Short – Short – Long – Short – Long – Short – Long

The "Long" restart period means that the CMV operator takes longer restart rests by resting until 7 AM of the next day in addition to the regular restart rest of 34 or 58 hours. The "Short" restart period means that the CMV operator takes regular restart rest of 34 or 58 hours. The first restart period is "Long" so the CMV operator takes extra rest until 7 AM the next day. The second and third restart periods are regular restart rests, so it starts working as soon as the restart hours are up. Similar to the first restart, in the 4th, 6th and 8th restarts, the CMV operator takes extra rest until 7 AM the next day in addition to the 34 or 58 restart rest hours. The fifth and seventh restart periods are regular restart periods. This pattern of restart periods gets repeated so the driver takes two consecutive long rests as it turns from the 8th restart to the 9th restart.

***Break Time Algorithm***

In order to make the model more closely reflect the driving patterns of actual truck drivers, a break period of either 30 minutes or one hour is imposed whenever the CMV operator drives four straight hours with more than one hour left until the destination. If the CMV operator hs equal to or less than one hour of driving left until the destination, the break period is not imposed since actual truck drivers would skip the break and continue driving.

The decision to break for 30 minutes or one hour is based on a random number generation with a 50 percent chance of each. According to DFACS survey, commercial truck drivers typically stopped for a break after 4 to 5 hours, and typically rested 30 to 60 minutes, with a median of 45.

***Split Sleeper Berth***

The model initiates the split sleeper berth algorithm whenever the CMV operator arrives at the pick-up or destination terminal and still has some time until the pick-up/delivery hour window. Specifically, if the minimum split sleeper berth is 2 hours and the daily rest is 10 hours, then the CMV operator takes a split sleeper rest if its waiting time at the pick-up or destination terminal is between 2 and 8 hours. If it needs to wait less than 2 hours, then it uses its duty time to wait for the shipment and if the wait is more than 8 hours, it uses its 10-hour rest to wait for the shipment.

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## APPENDIX (III)
## REVIEW OF SAFETY LITERATURE

### (III).1 INTRODUCTION

The purpose of the literature review was twofold: to identify and summarize material published or identified since the preparation of the 2003 RIA, and to identify material that has a bearing on the specific issues considered in proposed revisions to the 2003 HOS regulations. The revisions were specifically concerned with maximum driving time between rest periods, the issue of team driving where the driver works a series of short driving and rest periods and the effectiveness of long "weekend" breaks on accumulated sleep deficits. Much of the material is drawn from a literature survey commissioned by FMCSA specifically for this analysis, supplemented by relevant material identified by ICF staff as the work progressed.

The review is organized into broad subject headings as follows:

- Sleep and Performance Modeling;
- Survey-Type Studies of Truck Driver Fatigue and Performance;
- Instrumented and/or Laboratory Studies of Driver Fatigue and Performance; and
- Truck Crash Risks and Costs.

A brief summary is provided for each paper or report, containing a description of the study and principal findings relevant to the HOS analysis.

### (III).2 SLEEP AND PERFORMANCE MODELING

#### (III).2.1 Steven R Hursh, Daniel P. Redmond, Michael L. Johnson, David R. Thorne, Gregory Belenky, Thomas L. Balkin, William F. Storm, James C. Miller and Douglas R. Eddy "Fatigue Models for Applied Research in Warfighting", Aviation Space and Environmental Medicine, Vol. 75, Number 3 Supplement, 2004.

**Description of Study**

This paper describes the development and application of a comprehensive model for estimating the performance of personnel as a function of work and sleep schedules. The sleep and performance model, called the SAFTE model (Sleep, Activity, Fatigue and Task Effectiveness) is an outgrowth of an ongoing sleep and performance research conducted at the Walter Reed Army Institute of Research. Earlier, the WRAIR had developed a Sleep Performance model (WRAIR-SPM) based on laboratory tests of vigilance performance as a function of sleep and work schedules. This model was refined in a cooperative effort of several research organizations, and incorporation of research findings from a large number of sources to create the SAFTE model. This model incorporates two of the three main determinants of performance: circadian rhythm effects (both due to travel across time zones and due to the time-of-day of the working period) and sleep deprivation arising out of sleep and work schedules over the past few days. The model does not include time-on-task (TOT) effects. The SAFTE model has been incorporated into a working tool called FAST (Fatigue Avoidance Scheduling Tool) that provides a user-friendly interface to the SAFTE model for evaluating alternative schedules.

**Modeling Approach**

The core concept behind the SAFTE model is that of a sleep reservoir which individuals draw upon while awake and which is replenished by sleep. The overall structure of the SAFTE model is described below.

Alertness or performance is a function of three inputs:

- The amount of depletion of the sleep reservoir – research shows performance declines to the low level of 25% of that of a fully rested individual after 72 hours continuous wakefulness. A linear relationship between performance and sleep debt is used, although some research results suggest a non-linear relationship. Both the slope and shape of relationship can vary with the test task used to assess performance.

- Sleep inertia effects. Full wakefulness is not attained instantly on awaking. Instead there is a period, typically on the order of 1 to 2 hours, depending on sleep intensity and the current status of the sleep reservoir, during which performance recovers to a peak value, after which the normal decline with reservoir depletion resumes.

- Circadian rhythm effects. As discussed in Section 5.1.1, the circadian cycles affect alertness as a function of time of day and the individual's sleep/waking cycles over the past several days.

The model applies the results of numerous research studies of each effect to provide a continuous estimate performance levels over time. In principal, the model is not limited to one specific performance measure (such as the Psychomotor Vigilance Test (PVT) measure used in both this and the original truck HOS analysis), provided there is a sufficient research base to establish the relationships between task performance and the status of the sleep reservoir.

Replenishment of the sleep reservoir also depends on multiple inputs, as follows:

- Length of sleep. A non-linear function exists between the length of sleep and the amount of replenishment. The per-hour replenishment is less for the first three hours of sleep than later in the sleep cycle. The model also incorporates a factor for fragmented sleep, to quantify the reduction in sleep effectiveness due to frequent wakening, such as from external noise and vibration or a sleep disorder.

- Reservoir depletion level. Generally the lower the sleep reservoir, the greater the restorative effect of sleep. The term sleep intensity is used to quantify this effect.

- Circadian rhythm. Sleep is more effective (higher sleep intensity) around the low points in the circadian rhythm.

As with performance estimates, the SAFTE model applies the results of numerous research studies to estimate reservoir replenishment for a given period of sleep.

The authors conclude by identifying a number of areas where there are unexplained contradictions or anomalies in the available data, and where further research would be useful. One key area is the relationship between the performance metric and the actual demands of a specific task. In the HOS analyses, a relationship was developed between PVT and crash risk from truck driving simulator tests. Similar relationships are needed for other tasks, both to identify the most appropriate measure for a specific task and to establish a relationship for use in practical applications of the model.

## (III).3 SURVEY-TYPE STUDIES OF TRUCK DRIVER FATIGUE AND PERFORMANCE

### *(III).3.1 Arnold, P.K., Hartley, L.R., Hochstadt, D., and Penna, F. "Hours of work, and perceptions of fatigue among truck drivers." (1997). Accident Analysis & Prevention, 29 (4) 471-77.*

**Description**

This paper summarizes the results of a survey conducted with 1,249 truck drivers and 84 management representatives of transport companies. Data was collected in an Australian state which, at the time of the survey, did not restrict driving hours for heavy haulage drivers. Regulations were being discussed to limit driving to 14 hours in any 24-hour period, and restricting driving hours over the week to 72 hours. The aim of the study was to obtain information about hours of work and sleep from drivers operating in an unregulated environment. Drivers were asked to provide details about their driving and non-driving work schedules and the amount of sleep they had obtained in the past week. They were also asked to give an hour-by-hour record of activities, feelings of fatigue, and encounters with dangerous events over the 24 hours prior to the interview. Drivers and company representatives were interviewed about their perceptions about fatigue (e.g., factors perceived to be related to fatigue, causes, management) and whether they felt fatigue was problematic for truck drivers. A definition of fatigue was not provided. The authors concluded the paper by comparing their data on unregulated drivers' perceptions about fatigue to those reported by Williamson et al. (1992) for mainly regulated drivers.

**Relevant Findings**

- In a 24 hr period approximately 38% of drivers exceeded 14 hours of driving and 51% exceeded 14 hours of driving plus other non-driving work
- Approximately 17% of unregulated drivers exceeded 72 hours of driving in the week. When non-driving work is added, 30% worked in excess of 72 hours.
- Approximately 12% of drivers reported less than 4 hours of sleep on one or more working days in the week preceding the interview. These drivers are likely to be operating their vehicles while having a significant sleep debt.
- Approximately 20% of drivers who reported having less than 6 hours of sleep before starting their current journey reported 40% of the hazardous events

- Twelve percent of drivers who reported having had a crash in the previous 9 months identified fatigue as a contributing factor
- Five percent of the unregulated drivers reported having experienced a hazardous, fatigue related event, such as nodding off, on their current journey."
- 20% of drivers who reported having had less than 6 hours sleep reported 40% of the hazardous events."
- Many drivers and company representatives reported fatigue to be a problem for other drivers but considered themselves or their companies' drivers to be relatively unaffected by fatigue
- The authors concluded the paper by comparing their data on unregulated drivers' perceptions about fatigue to those reported by Williamson et al. (1992) for mainly regulated drivers. The results suggest that unregulated drivers perceive that fatigue is a problem for themselves less frequently than regulated drivers (10% versus 28-35%). Similarly, fewer unregulated drivers considered fatigue to be a general industry problem than did regulated drivers (39% versus 78%). These differences in frequency ratings may be due to differences in the attention paid to fatigue as a safety problem in regulated and unregulated states.

***(III)3.2 Feyer, A.M., Williamson, A., Friswell, R. "Balancing work and rest to combat driver fatigue: An investigation of two-up driving in Australia." (1997). Accident Analysis & Prevention, 29 (4) 541-53.***

**Description of Study**

This study was designed to examine the nature and impact of two-up driving operations on fatigue. Long-haul truck drivers were measured on a 4,500 km round trip. The driving operations of single driving (i.e., a solo driver) and two-up driving (i.e., pair of drivers operating a truck continuously, alternating work and rest) were compared.

A "between groups" design was used for this study, in which each participant only drove one evaluated trip using his regular operation –either two-up or single. Drivers were asked to drive a 4 to 5 day round trip of approximately 4500 km. in Western Australia. At the time of the study, the state of Western Australia did not have enforced driving hours regulations. Twenty-two of the 37 participants regularly worked two-up operations on the selected route and 15 regularly worked as single drivers. A variety of measures were used to assess drivers' fatigue and its effects such as heart activity, speed and steering wheel angles, auditory reaction time tasks, cognitive tests, and subjective measures of fatigue. Prior to starting their trip, participants were also asked to complete questionnaires about their general state of physical health, their lifestyle and their pattern of work/rest in week preceding study.

**Relevant Findings**

- "Irrespective of driver operation, fatigue increased for drivers on long-distance trips typical of remote zone driving."
- "Two-up drivers reported and showed evidence of greater fatigue than single drivers before the trip started and appeared to be more fatigued overall for most of the trip."

- “Over the homeward leg of the trip, two-up drivers reported no change in the level of fatigue, with fatigue having peaked at mid trip. For single drivers, in contrast, fatigue peaked at the end of the homeward leg, despite considerable recovery at mid trip.”
- While overall the two-up group showed greater fatigue compared to single drivers, some ways of doing two-up (e.g., overnight stationary rest, shorter trip duration) were less fatiguing than single driving.
- Two-up drivers started the trip more fatigued and this “disadvantage remained for most of the trip”… “but was most marked over the first leg of the trip where fatigue for two-up drivers continued to worsen at a greater rate than for single drivers.”
- “… where work practices kept the fatigue under control, such as on shorter two-up trips and two-up trips incorporating overnight stationary rest, breaks were more likely to be helpful. In contrast, where fatigue was allowed to build-up, such as on single trips and on very long two-up trips without stationary rest, breaks did not provide relief once fatigue had accumulated.”

- Overnight stationary rest for two-up drivers at mid trip, was associated with dramatic reductions in fatigue levels after the break, and allowed these drivers to finish the trip with the lowest levels of fatigue of any group, including single drivers. Two-up drivers who had no stationary rest, but had the shortest trip duration of any group showed an overall increase in alertness over the homeward journey, finishing the trip at roughly pre-trip fatigue levels.”

- Working hours regulations for long distance drivers are primarily based on limitations to periods of driving and rest within a trip, largely in isolation from overall scheduling patterns. In contrast, the current findings strongly suggest that effective management of fatigue involves considerations of the whole pattern and timing of work and rest

### *(III)3.2 Hakkanen, H. and Summala, H. (2000). “Driver sleepiness-related problems, health status, and prolonged driving among professional heavy-vehicle drivers.” Transportation Human Factors, 2(2), 151-171.*

**Description of Study**

This paper summarizes the results of a survey conducted with 567 Finnish professional drivers who responded to a questionnaire, out of 2,000 randomly-chosen drivers who were invited to take part. The drivers had 5 different work descriptions, and were part of a non-political organization promoting truck drivers’ interests. The mailed questionnaires were completed anonymously. The main purpose of this survey study was to examine the relation between truck drivers’ health and sleepiness-related problems while driving. In addition, factors most likely to predict increased driver sleepiness were identified. Furthermore, frequency of non-compliance with the driving-hours regulations (in terms of driving more than 10 hours) and drivers’ comprehension regarding the suitability of the regulation were surveyed. In Finland, truck driving hours are subject to control by EC regulation No. 3820/85, according to which the maximum driving time is 10 hr and the resting time is 11 hours per each 24-hr period. Previous studies had indicated that all drivers do not follow the limits set by the regulation.

The questionnaires requested information on the drivers' preceding 3 months' work, possible sleepiness-related problems at work and their opinions about maximum permitted driving times. In addition, they were also given parts of the Basic Nordic Sleep Questionnaire and the Epworth Sleepiness Scale to estimate the "prevalence of suspected sleep apnea syndrome and to collect data of driver's sleep history." Drivers were also asked questions about their self-perceived general health status and the occurrence of any chronic illnesses.

**Relevant Findings**

- "The results of the study indicated that approximately one third of all the drivers drive generally more than 10 hr, which violates the EC regulation."
- "More than 70% of the drivers felt that the maximum permitted driving hours should be at least 11 hr per a 24- hr period".
- Nineteen per cent reported having dozed off at least twice while driving, and 8% reported a near-miss situation due to dozing off during the past 3 months.
- "Sleepiness-related problems while driving appeared across all driver groups (i.e., long haul, short haul, bus drivers, drivers transporting dangerous goods, drivers transporting wood), including drivers transporting dangerous goods and bus drivers, and were strongly related to prolonged driving, sleep deficit and drivers' health status. The effects of the latter factors were interactive and cumulative: Frequent sleepiness-related problems occurred in more than one half (52.3%) of the "drivers with the combination of prolonged driving, sleep deficit, and lowered self-perceived health."
- The 10% of drivers who were suspected to have sleep apnea syndrome (note: screening through questionnaires only) reported having experienced significantly more frequent sleepiness-related problems while driving although they did not report a significant increase in the frequency of sleepiness-related accidents.
- Less healthy drivers were both significantly older and tended to work longer hours and report greater sleep deficits and more problems with alertness and sleepiness while driving. These differences extended particularly to drivers reporting chronic illness in the last three years.
- The evidence for a cause-and-effect connection between a chronic illness and sleepiness-related problems while driving was somewhat mixed. While "the univariate comparison between those with an illness and others suggested a marked difference in sleepiness-related problems," the "logistic regression analysis showed that when other relevant factors were controlled (e.g., age, driving time) the effect of a chronic illness was no more significant whereas perceived health status better explained sleepiness-related problems while driving." The authors suggested that this result might be partly due to the fact that the discovered illnesses were rather heterogeneous. Increased odds of having more frequent difficulties in remaining alert if the driver self-perceived as having no more than a satisfactory health.
- When all the relevant factors were controlled, shift type and driving time were the only work-related variables that significantly predicted more frequent difficulties in remaining alert ($p<.05$ and $p<.05$, respectively). The odds of having experienced more frequent difficulties increased by a factor of 1.85 if the driver had been driving a

night or irregular shift and by 3.57 if the driver had been driving more than 17 hr (compared to fewer than 6 hr driving).

- The authors conclude that the results give unreserved support for regulating driving hours and increase concern of the connection between professional drivers' health status and sleepiness-related problems while driving.
- Drivers were more apt to have frequent difficulties remaining alert if they had been driving a night or irregular shift, or had been driving more than 17 hours.

### *(III)3.3 Morrow, P.C. and Crum, M.R. (2004) "Antecedents of fatigue, close calls, and crashes among commercial motor-vehicle drivers." Journal of Safety Research, 35 (1).*

**Description of Study**

This paper summarizes the results of a survey of commercial motor vehicle drivers in 116 trucking firms. The purpose of the study was to identify factors (i.e., fatigue inducing and company safety management factors) relevant to the prediction of driving while fatigued, close calls due to fatigue, and actual crash involvement among CMV drivers engaged in intra- and interstate truck driving.

Thirty-two of the 116 firms in the study were top safety-performing firms, 53 from average firms and 31 from poor performing firms. Drivers were asked a number of questions about fatigue-inducing factors such workload, schedule regularity, difficulty finding rest places, adequacy of sleep, insufficient recovery, per cent of time loading/unloading. In addition, participants were asked about the perceived safety climate in their company. The authors formulated 11 perceived safety climate items (e.g., "Our Company makes driving safety a top priority") and asked drivers to record their level of agreement). Finally drivers were asked about their fatigue while driving (e.g., nodding off while driving, etc.,), as well as frequency of close calls and crashes.

The authors proposed three models to account for the variation in fatigue while driving, close calls due to fatigue, and crash involvement. Proposition 1 specified that fatigue-inducing factors would account for variation in these outcome measures. Proposition 2 specified that "company safety management practices should account for variation in the outcome measures, controlling for fatigue-inducing factors associated with truck driving work." Proposition 3 contended that "fatigue while driving accounts for variation in the frequency of close calls due to fatigue and crash involvement, after controlling for fatigue-inducing factors and company safety management practices."

**Relevant Findings**

- "Fatigue-inducing factors inherent in driving work and safety practices" (e.g., schedule regularity, difficulty finding a place to rest, adequacy of sleep when working, insufficient recovery, per cent of time loading/unloading, etc.,) "accounted for appreciable variation in driving fatigue (R squared =. 42) and close calls (R squared = .35), but not crash involvement." Self-report measures were used to assess fatigue (i.e., 3-item measure). Crash involvement was measured using the sum of two items: 1) reportable accidents (to the company) and 2) chargeable accidents that drivers had been involved with over the last 2 years.

- Approximately one-fifth of the drivers reported having one or more reportable accidents, and approximately 4% reported having chargeable accidents. The raw data was adjusted to account for exposure and expressed on a per 100,000 miles basis. Drivers with reportable accidents had between .32 and 6.41 crashes per 100,000 miles, while those reporting chargeable accidents had between .29 and 1.03 crashes per 100,000 miles. The measure exhibited a Cronbach alpha of .85.

- "Driving while fatigued accounted for incremental increases in the amount of variation in close calls, after consideration of inherent factors and safety practices."

- Safety practices (e.g., establishment of a strong safety culture, dispatcher scheduling practices, company assistance with fatiguing behaviors such as loading and unloading) have considerable potential to offset fatigue-inducing factors associated with truck driving work."

- While there is an assumption that employees will use off-duty time to engage in restorative activities, the insufficient recovery results reported in this study, led the authors to conclude that "drivers do not necessarily spend their non-work time in this manner". While drivers may not engage in job-related activities during their recovery periods, some drivers do engage in activities and sleep patterns that lead them to report back to work already fatigued. 47% of the drivers reported that they started the work week fatigue with some regularity. The authors note that the results "suggest that the potential misuse of off-duty time can be mitigated by the presence of a strong safety climate or enactment of policies targeted at fatigue-inducing activities (i.e., companies can act to reduce this problem)."

### *(III)3.4 Williamson, A., Feyer, A., and Friswell, R. (1996). "The impact of work practices on fatigue in long distance truck drivers." Accident Analysis & Prevention, Vol. 28, No. 6, 709-71*

**Description of Study**

The aim of this Australian study was to investigate the relationship between staged driving and fatigue. Professional truck drivers completed a 12 hour, 900 km trip under each of three driving regimes – a relay (staged) trip, a working-hours-regulated one-way (single) trip, and a one-way (flexible) trip with no working hours constraints. All of the observed trips took place overnight. The staged trip entailed driving from Sydney or Melbourne to the trip midpoint (Tarcutta), exchanging trucks or loads with a driver coming in the opposite direction, and then returning to the point of origin. "The single one-way trips involved driving directly from Sydney to Melbourne, and the flexible one-way trips involved driving from Melbourne to Sydney." "Under the regulations, drivers on single and staged trips were obliged to break for 30 minutes after each five hour period. Under the flexible regime drivers could choose to take breaks as often or as rarely as they needed with no constraint on the time taken to complete the trip." All of the observed trips took place overnight. Most trips began in the early evening and night between 16:00 and 23:59. The three driving regimes did not differ significantly in starting time. While, on average, the staged trips took longer to complete than flexible trips, the trip lengths differed by only 40 minutes. The study employed subjective (e.g., Stanford Sleepiness Scale, etc.), physiological (e.g., heart rate), and performance (e.g., speed, steering variability, reaction time, etc.) "measures to examine the relationship between the characteristics of staged driving and the development of fatigue.

**Relevant Findings**

- Although there was some evidence that fatigue developed differently within the three driving regimes (staged, single, and flexible), the levels of fatigue experienced by drivers increased markedly over all the trips
- Drivers tended to feel most fatigued on staged trips and least fatigued on single trips, however, this pattern was in evidence before driving commenced and post trip had not been modified by the intervening driving regime.
- "None of the regimes demonstrated any overall advantage in combating fatigue compared to the other regimes."
- It is clear from the findings that "even relatively short 12-hour trips are tiring, and that effective strategies for fatigue reduction need to be identified."
- The number of breaks taken increased across flexible, single and staged trips, suggesting an increasing need for rest as a function of driving regime. However, breaks were taken after similar periods of driving for the three trip types (Table 1). The longest driver period (4.5 hours) routinely occurred before the first break and the shortest drive period (2.5-3 hours) preceded the second break
- Pre-trip level of fatigue appears to be an important determinant of later fatigue. This raises questions about the ongoing work schedules under which long distance drivers operate, "and highlights the need to allow adequate rest and recuperation between trips and between blocks of trips to prevent chronic sleep loss and to reduce fatigue."

## (III)4 INSTRUMENTED AND/OR LABORATORY STUDIES OF DRIVER FATIGUE AND PERFORMANCE

### *(III)4.1 Baas, P.H. (Transport Engineering Research New Zealand (TERNZ)), Charlton, S., and Bastin, G. (2000) "Survey of New Zealand truck driver fatigue and fitness for duty." 4th International Conference on Fatigue and Transportation, Fremantle, Western Australia.*

**Abstract**

This study involved Interviews and simulator-based performance test conducted at depots, wharves, markets and other locations throughout the North Island of New Zealand throughout the day and night. The reported analysis covers results from the first 100 drivers.

The survey was conducted with 600 truck drivers at depots, markets, etc. around the North Island of New Zealand. Interviews focused on "driver demographic and work/rest patterns, drivers' attitudes towards fatigue, propensity towards daytime sleepiness, and a self-assessment of the driver's momentary level of fatigue." A simulator-based performance test of driving was also undertaken on adapted version of the commercially available truck operator proficiency system (TOPS). "In the course of its development, TOPS passed through several verification and validation stages resulting in a pass/fail criterion for driver performance." The performance test consisted of a standard driving task, a dual-axis sub-critical tracking task, and a tertiary or side-task requiring driver monitoring and periodic responses. “Calculation of pass/fail scores was based on five performance index coefficients (linear combinations of the performance variables). For each driver the five performance indices were calculated and compared to established performance criteria for each of the indices. The indices focused on the following five general categories: curvative error variability, divided attention response time variability, throttle activity variability, steering activity variability, longitudinal speed variability. A driver was required to obtain a passing score on each of the five performance indices to receive a passing score for the trial as a whole.”

**Relevant Findings:**

- The drivers’ typical workday length ranged from 6 to 15 hr with an average across all drivers of 11.89 h and a S.D. of 1.683.
- “The average number of days driving per week ranged from 3 (relief and part-time drivers) to 7, with an average of 5.35 days, standard deviation of 0.557 days.”
- Drivers typically rated fatigue to be a problem for other drivers (21%) more often than for themselves (8%).
- A much lower proportion of drivers rated fatigue as “never” being a problem for them as did drivers in Hartley et al’s study (13% as opposed to 35.5% in Hartley et al).
- 33% of drivers reported that they did not comply with the hours of service regulations (11 hours driving in one day) , and only 69% reported compliance with the requirement for minimum rest of 9 hours
- Drivers had an average of just one and a half meals per day (0.5 of a meal was defined as a light snack, usually while driving).
- The average Epworth Sleepiness Score of 7.53 (S.D. of 4.47) was substantially higher than the average score of 5.7 for truck drivers and 6.2 for automobile drivers reported in previous research (Maycock, 1995).
- 91% of all drivers passed all five of the performance criteria for the performance test on the simulator. “Of the 9% of drivers displaying driving performance below the criterion level, eight drivers failed the first performance criterion, a linear combination of measures predominantly associated with curvature error variability.”
- “Of the drivers’ activity and demographic measures, two were found to be particularly reliable predictors of simulator task performance: average distance driven per shift and driver age, $F(2, 98) = 8.42$, $P<0.01$. Drivers with an average daily route of fewer than 250 km and drivers 37 years and older were much more likely to fail the performance test.” The authors noted that at this stage it was unclear “how to interpret the route length and age effects in the TOPS results”

***(III)4.2 Balkin, T., Thome, D., Sing, H., Thomas, M., Redmond, D., Wesensten, N., Williams, J., Hall, S., and Belenky, G. (2000). "Effects of sleep schedules on commercial motor vehicle driver performance." Department of Transportation, Federal Motor Carrier Safety Administration.***

***FMCSA Tech Brief, 2000/09 (FMCSA-MCRT-00-015)***
***"Effects of sleep schedules on commercial motor vehicle driver performance – Part 2"***

Note: These studies were the primary source used to form a relationship between PVT and truck crash risk, and also contributed to the relationships embedded in the SAFTE/FAST sleep and performance model.

**Description of Study**

The studies were conducted to gather and analyze data on commercial motor vehicle driver rest and recovery cycles, effects of partial sleep deprivation, and prediction of subsequent performance. The project was composed of two studies

*Field Study:*

Study involved actigraphic assessment of sleep and driver/sleep logs, conducted with long and short haul CMV drivers over 20 consecutive days. The drivers wore the Walter Reed wrist actigraphs at all times except when bathing or showering. In addition they completed sleep logs on driver's daily log sheets to gather subjective information about sleep times, sleep latency, arousals during sleep, alertness upon awakening, naps (number and duration), and self-reported caffeine, alcohol and drug use. The data from each actigraph were downloaded to a personal computer, and each 24-hour actigraph recording period was examined for sleep in its entirety regardless of the duty status type or length indicated on the daily log sheet.

*Laboratory Study:*

Primary objectives of the laboratory study were to "1) determine the effects of four sleep/wake schedules on alertness and performance, and 2) develop an algorithmic model to predict performance on the basis of prior sleep parameters." Drivers had 3 days of orientation and baseline sleep in the laboratory before data collection commenced over 7 days of performance testing with 3, 5, 7, or 9 hours of sleep each night. The recovery period, that followed, lasted 4 days with 8 hours in bed each night. A wide variety of measures were utilized. Measures consisted of the psychomotor vigilance task (PVT), the cognitive performance assessment battery, driving simulator tasks (e.g., lane tracking) as well as sleep latency, EMG and sleepiness ratings. In addition to these measures, a number of health measures were taken (e.g., tympanic temperature, heart rate, and blood pressure). Primary objectives of the laboratory study were to 1) determine the effects of four sleep/wake schedules on alertness and performance, and 2) develop an algorithmic model to predict performance on the basis of prior sleep parameters." In addition to psychomotor vigilance

**Principal Findings**

***Field Study:***

- Both long- and short-haul drivers averaged approximately 7.5 hours of sleep per night, which is within normal limits for adults. "However, the short-haul drivers tended to consolidate their daily sleep into a single, off-duty period, whereas long-haul drivers obtained approximately half of their daily sleep total as daytime naps and/or during sleeper-berth time."
- As long-haul drivers obtained almost half of their daily sleep during work-shift hours (mainly sleep-berth time), it appears that they spend a significant portion of the work shift in a state of partial sleep deprivation, until the opportunity to obtain on-duty recovery sleep presents itself.
- There was no off-duty duration that guaranteed adequate sleep for the long or short haul drivers. As drivers likely use a substantial portion of their off-duty time to attend to personal business, off-duty time must be of sufficient duration to allow drivers to accomplish these tasks and to obtain sufficient sleep. This may be particularly important for long-haul drivers, who often did not sleep at all during off-duty periods.
- The bulk of the first (main) daily sleep bouts for short-haul drivers were initiated between 2000 and 0200 hours. Sleep bouts initiated at these times lasted longer (i.e., clustered between 6 and 10 hours) than sleep bouts initiated at other times of day. Several of the sleep bouts initiated between these times lasted longer than 12 hours.
- Similar to the short-haul drivers, the majority of long-haul drivers' first sleep bouts were initiated between 2200 and 0359 hours. However, long-haul drivers initiated their first sleep bouts more frequently during 0000 and 0359 hours. The duration of long-haul drivers' first sleep bouts clustered between 6 and 10 hours in duration. Sleep bouts exceeding 10 hours in duration were uncommon and none exceeded 12 hours. Some sleep bouts were initiated in the early and late afternoon hours (1200 to 1959) and, unlike short-haul drivers, almost half of the first sleep bouts initiated during this time frame were longer than 4 hours in duration.
- There were large day-to-day variations in total sleep time for drivers in both groups. Sleep times varied for some long and short-haul individuals by up to 11.2 hours across the 20 study days for the long and short-haul drivers. Other drivers maintained more consistent sleep/wake schedules. Some individuals showed a pattern that suggested chronic sleep restriction with intermittent bouts of extended recovery sleep. The authors felt that this suggested that although work/rest schedules can be devised to help minimize CMV driver sleep debt, optimal enhancement of driver alertness and performance will require additional and imaginative approaches.

***Lab Study:***

- On average, subjects slept 2.9, 4.7, 6.3, and 7.9 hours for the 3, 5, 7, and 9-hour time in bed conditions respectively, and displayed dose-dependent performance impairment related to partial sleep loss. (As can be deduced from the above sleep times, as sleep restriction was more pronounced, sleep latency periods declined, resulting in greater sleep efficiency or proportionally more sleep in the available period.)

- Performance in the 3-hour sleep group typically declined below baseline within 2 to 3 days of sleep restriction.
- Performance in the 5-hour sleep group was consistently lower than performance in the 7- and 9-hour sleep groups.
- Performance in the 7- and 9-hour sleep groups was often indistinguishable and improved throughout the study. However, the authors did note that "even a relatively small reduction in average nighttime sleep duration (i.e., 6.3 hrs of sleep – the average amount of sleep obtained by the 7-hr group) resulted in measurably poorer performance – e.g., on the PVT. This decrement was maintained across the entire consecutive days of sleep restriction.
- Virtually no negative effects on performance were seen in the 9-hour sleep group.
- Sleep restriction effects were consistent. The degree to which "sleep restriction impaired performance was measure-specific". "Across tasks, speed and throughput were consistently affected". "In general, performance for the 3- and 5-hour sleep groups was below that of the 7- and 9-hour sleep groups." "Thus, restricting sleep resulted in dose-dependent performance impairment."
- All cognitive tasks were sensitive to differential sleep restriction.
- The PVT was the most sensitive measure. (It was also the performance measure which was the most resistant to changes in performance due to learning, an important issue when effects over many days are being examined.) Even the 7-hour group with 6.3 hours of sleep showed decreased performance using this measure across the 7 days.
- The majority of driving performance measures (e.g., increased lane-tracking variability increased driving speed, increased speed variability and increased running-off-road accidents) also showed dose-dependent and/or cumulative sleep restriction effects.
- Following chronic sleep restriction, the first 8 hours in bed (6.5 hours of sleep) was insufficient for restoration of performance on the PVT task.
- During the 4-day recovery phase (8 hours in bed each night), 5- and 7-hour sleep groups showed minimal or no recovery, remaining consistently below the 9-hour sleep group and below their own baseline levels for the PVT.
- The 3-hour sleep group showed some recovery for the PVT on the first day and more on subsequent days but also remained well below their own baseline and below the performance of the other groups.
- Subjects' recovery to baseline or near baseline levels of performance on the PVT often required a second or third night of recovery sleep.
- These data suggest that after sleep debt has occurred (3, 5, 7 hr time in bed) a single bout of 8 hours of night sleep leads to recovery but not full recovery. While further sleep is required for full recovery, the number of subsequent sleep periods to reach full recovery is unknown. For the 3 hour group, the data suggests that even 3 nights of normal sleep (8 hours spent in bed on each night) is not sufficient to restore performance to baseline levels (depending on the task). This suggests that full recovery from substantial sleep debt requires recovery sleep of extended duration (i.e., more than 8 hours of normal-duration sleep). This is a unique finding and requires replication.

- In contrast to the findings concerning PVT performance, the accident rate went back to baseline after one recovery day for all groups. In addition, lane position variability was near, but not quite back to baseline for all but the 9-hour group.
- On recovery days lane position variability was slightly worse for the 9-hour group who, after being allowed 9 hours in bed each night during the work period, were restricted to 8 hours of sleep.

- "The extant level of daytime alertness and performance capacity is a function not only of an individual's circadian rhythm, time since the last sleep period, and duration of the last sleep period, but is also a function of his/her sleep history, extending back for at least several days."
- Following more severe sleep restriction (e.g., the 3-hr group), recovery of performance was not complete after 3 consecutive nights of recovery sleep …this suggests that full recovery from substantial sleep debt requires recovery sleep of extended duration.

***(III)4.3 Dingus, T., Neale, V., Garness, S., Hanowski, R., Keisler, A., Lee, S., Perez, M., Robinson, G., Belz, S., Casali, J., Pace-Schott, E., Stickgold, R., Hobson, J.A., The Impact of Sleeper Berth Usage on Driver Fatigue. FMCSA, FMCSA-RT-02-050, Washington, DC, November 2001.***

***Federal Motor Carrier Safety Administration. "Impact of sleeper berth usage on driver fatigue: Final Report." (2002). Report Number: FMCSA-RT-02-070***

***Klauer, S.G., Dingus, T.A., Neale, V.L. and Carroll, R.J. (2003) "The effects of fatigue on driver performance for single and team long-haul truck drivers." Driving Assessment 2003 – The Second International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design. Park City, Utah.***

NB All quotes are from FMCSA summary.

**Description of Studies**

This report documents research that was conducted on sleeper berth usage. In addition to focus groups with long-haul operators a field study was conducted on sleeper berth usage for single and team drivers. The report outlines a number of factors, discovered in a series of 10 focus groups, which are important to successful sleeper berth usage for single and team drivers. Based on the results of the focus groups and an accompanying literature review, the researchers designed an on-road study with 56 drivers (47 male, 9 female; mean age=42.6 years) constituting 13 teams and 30 single drivers, to assess the effects of sleeper berth usage on sleep, driver error and critical incidents. In this study, long-haul truck drivers operated heavy trucks for a minimum of six continuous days, with the typical run being seven to 10 working days, on their regularly assigned route. Data collection systems were installed on the tractors used by the drivers to collect sleeper berth environmental data, driving performance information, video of the driver's face, and subjective alertness ratings and data from the Nightcap sleep system. Data (i.e., computer and video) were collected prior to and during critical incidents such as lane and steering deviations.

## Relevant Findings

### *Focus Groups*

- "Team versus single driving was identified as a very important factor for drivers relating to quality of sleep." Drivers either loved or hated team driving and discussed various issues relevant to their preference (e.g., trust, partner's driving ability, driving smoothly, etc.). Drivers also discussed various equipment issues with respect to comfortable sleeping arrangements (e.g., noise, air-ride vs. spring-ride trucks, etc.,)

### *Field Study: Team Driving vs. Single Driving*

- Single drivers were involved in significantly more critical incidents than team drivers. They were involved in "four times the instances of "very/extremely drowsy" observer ratings than were team drivers, and were more likely to push themselves to drive on occasions when they were very tired."

- More than one-half of the most severe of the critical incidents were caused by four of the thirty single drivers. In contrast, team drivers were generally very successful at avoiding circumstances of extreme drowsiness, drove much less aggressively and made fewer errors than single drivers.

- The main effect for segment of day was significant ($p < 0.05$). Team drivers tended to exhibit critical incidents associated with extreme fatigue during the (morning and night hours (morning: 04:00 to 11:59; afternoon: 12:00 to 17:59, night: 22:00 to 03.59). Single drivers "tended to show fewer extreme fatigue-related critical incidents during the morning hours, with gradually more critical incidents being attributed to the very drowsy categories during the evening and nighttime hours". The authors note that single drivers "were exhibiting signs of extreme fatigue during all hours of the day while team drivers only showed signs of fatigue during the nighttime and morning hours."

- Overall, team drivers were able to better manage their fatigue and critical incident involvement than were single drivers. This may be because team drivers are more likely to effectively trade-off driving duties with their partner prior to becoming extremely fatigued. It is also possible that, in effect, drivers undergo a natural "screening" process. Focus group participants noted that team drivers must be trustworthy with regard to their driving ability and be considerate of their resting partner.

### *Field Study: Quality of Sleep*

- A number of findings indicated that the quality and depth of sleep was worse (e.g., more sleep disturbances) on the road, particularly for team drivers. They found that while the vehicle was in motion, the noise and motion environment in the sleeper berth degraded the drivers' sleep.

*Field Study: Hours of Service*

- Based on a report by Wylie et al., (1996), there were relatively few instances (about 2.2 percent) of "extreme drowsiness," with most of these instances being experienced by single drivers, again with a high rate of the occurrence of this level of fatigue on the second or third shift after the first day of a multi-day drive."

- The authors note that it "appears that the combination of long driving times and multiple days provides the greatest concern, with several results pointing to the presence of cumulative fatigue." As a result they believe that the length of shifts in the later stages of a trip must also be considered. However, the authors point out that "critical incidents and/or driver errors did not increase directly with the hours beyond the regulation," and that "there was a substantial decrease in the rate of critical incidents during some of the more extreme violations." However, they do caution that this should not be interpreted to mean that hours of service should be expanded due to the following two reasons: "First, it may be possible that the drivers were making a point to driver more carefully and cautiously because they were operating outside of the regulation and did not want to get stopped by law enforcement officials. Alternatively, they may have only risked driving outside of the regulations because they felt alert and knew that they could continue to drive safely."

### *(III)4.4 Gillberg, M., Kecklund, G., and Akerstedt, T. (1996). "Sleepiness and performance of professional drivers in a truck simulator – comparisons between day and night driving." Journal of Sleep Research, 5, 12-15.*

This paper summarizes a study comparing daytime and night-time performance of professional drivers on a simulated driving task. The authors noted that to their knowledge no studies had been conducted reporting on the effects of sleepiness on night driving performance in a dynamic truck simulator using professional drivers as subjects. The secondary purpose of the study was to test whether a nap, or a rest pause, would affect performance.

Nine professional drivers participated 4 times in a counterbalanced repeated measures design. "The conditions were day driving (DAYDRIVE), night driving (NIGHTDRIVE), night driving with a 30 minute rest (NIGHTREST), and night driving with a 30 minute nap (NIGHTNAP)." Time of day was not specified. "Each condition consisted of three consecutive 30-min periods." The 30-min duration of each period was an adaptation to the maximal continuous driving period allowed by the simulator software. "For the DAYDRIVE and NIGHTDRIVE all periods were spent driving while the second period was either a rest pause or a nap for the other two conditions." "Mean speed, standard deviation of speed and, standard deviation for lane position were recorded. Self ratings of sleepiness (e.g., Karolinska Sleepiness Scale) were obtained before and after each 30-min period. Reaction time tests and 10 minute standardized EEG/EOG recordings were obtained before and after each condition". EEG/EOG recordings were obtained before and after each condition. EEG/EOG were also recorded continuously during driving.

### Relevant Findings

- The authors noted that despite the relatively short task (continuously driving for only 30 minutes at a time) statistically significant differences between day and night driving performance could be demonstrated. The effects on driving were small but significant: night driving was slower, with a higher variability of speed, and higher variability of lane position.
- Subjective and EEG/EOG sleepiness were clearly higher during the night conditions.
- Reaction time performance was not significantly affected by conditions.
- The authors noted that the task per se affected alertness, as indicated by the clear increase in subjective and electrophysiological sleepiness as well as in reaction times over the three periods even for the day driving condition.
- Neither the nap nor the rest pause had any effect. The authors note that a nap of the same duration during the day, on the other hand, has been shown to have clear positive effects. They felt that as sleep inertia tends to be more pronounced with the longer wake times that will precede night naps (Dinges, 1985), this might have obscured the possible positive effects of the nap in the present experiment. It is clear, however, that the nap did not have a negative effect which could have been the result if severe sleep inertia had occurred. The authors conclude that the most reasonable explanation to the lack of nap effect is that it was too short to counteract the low levels of alertness during the circadian trough after an extended time awake.

***(III)4.5 Hanowski, R. J., Wierwille, W. W., Gellatly, A. W., Early, N., and Dingus, T. A. (2000). "Impact of local short haul operations on driver fatigue." Department of Transportation Federal Motor Carrier Safety Administration.***

### Description of Study

This paper summarizes the results of an on-road field study focusing on the fatigue experienced by local/short haul truck (L/SH) drivers (i.e., trips less than 100 miles from home base) on typical workdays, whose vehicles were instrumented with data collection equipment. Forty-two male L/SH drivers (mean age = 31) participated in the study. Drivers completed 2 weeks of Monday-Friday daytime driving on normal delivery routes that were within 100 miles of home. Their distribution of work consisted of driving (28%), loading/unloading (35%), other assignments (26%), waiting to unload (7%), eating (2%), resting (0.5%) and other activities (1.5%).

The authors used subjective, objective and physiological measures to assess fatigue, inattention and drowsiness. Subjective measures included self-report on levels of stress. Objective measures included the degree of eyelid closure. Physiological measures included indications of sleep quantity and quality as collected by wrist activity monitors. In addition the “black box” data collection equipment installed in the truck collected driver performance associated with “critical incidents” (i.e., near-crash events). Several small video cameras were used to monitor each truck driver and surrounding traffic situation, and sensors collected date from the vehicle’s instruments. The authors conducted analyses of videotape of the three-minute interval preceding the start of a critical incident. An incident was defined as a control movement exceeding a threshold based on driver or analyst input. Analysts recorded eye transitions and the proportion of time that the driver's eyes were closed/nearly closed, or off the road, during these three-minute intervals.

**Relevant Findings**

- Over the two-week period, there were 77 incidents (average 1.8 per driver) where the driver was judged to be at fault. Inattention was thought to be involved in 57 critical incidents, and fatigue a contributor to 28 critical incidents (i.e., 20.8% of incidents where the L/SH driver was judged to be at fault).
- The majority of the L/SH driver at fault critical incidents were caused by about one-quarter of the drivers: ten of the 42 drivers were involved in 86% of the incidents.
- The younger and less experienced drivers were significantly more likely to be involved in critical incidents and exhibited higher on the job drowsiness.
- "Drivers tended to be involved in fatigue-related incidents earlier in the workweek. There were no fatigue-related critical incidents after the fourth day of the workweek."
- The highest frequency of driver-at-fault incidents was between noon and 1 PM. The increase in incidents during these periods may be attributed to increased exposure.
- Drivers demonstrated, to a statistically significant level, signs of fatigue for a time period immediately preceding incident involvement where the L/SH driver was judged to be at fault.
- During the study, the drivers' mean sleep was 6.43 hours per night (sleep log) and 5.31 hours based on the Actiwatch (developed by Mini Mitter Co., Inc.).
- Data was divided into two groups where fatigue was apparent or not apparent. "To classify incidents into one of these two groups, threshold values for PERCLOS and OBSERV were set such that fatigued drivers were defined as having PERCLOS greater than or equal to 0/08, or an OBSERV value greater than or equal to 40. If an event did not meet one of these criteria, then the driver was deemed to be 'not fatigued.'" Drivers who showed evidence of fatigue and were involved in fatigue-related incidents had less sleep and of a poorer quality than drivers who did not show signs of fatigue. The drivers from the beverage company typically worked 10 to 11 hours per workday. The snack food drivers worked roughly 12 hours per workday.  The majority of drivers worked five days per week.
- The self-reported amount of sleep and quality of sleep for the night before the incident were less when the driver was categorized as being fatigued. Drivers in the fatigue group had 5.33 hours of sleep compared to 6.13 hours in the non-fatigue group.
- "…much of the fatigue that the drivers' experienced was brought with them to the job, rather than being caused by the job." The authors concluded that off-duty behavior was the "primary contributing factor in the level of fatigue that was demonstrated during the workday."
- Drivers in the fatigue group spent more hours driving during the day of the critical incident as compared to drivers in the no-fatigue group.

***(III)4.6 O'Neill, T.R., Kruegar, G.P., Van Hemel, S.B., and McGowan, A.L. (1999). "Effects of operating practices on commercial driver alertness." Rep. No. FHWA-MC-99-140, Office of Motor Carrier and Highway Safety, Federal Highway Administration, Washington, D.C.***

***O'Neill, T.R., Krueger, G.P., Van Hemel, S.B., McGowan, A.L. and Rogers, W.C. (1999) "Effects of cargo loading and unloading on truck driver alertness." Transportation Research Record, 1686, pp. 42-48.***

***Rogers, W. (2000) "Effects of operating practices on commercial driver alertness." Proceeding of the Conference Traffic Safety on Two Continents held in Malmo, Sweden, September 20 – 22, 1999.***

***Tech Brief (1999) (FHWA-MCRT-99-008) "Effects of operating practices on commercial driver alertness."***

**Description of Study**

This project consisted of focus groups, a driver survey and interviews with CMV drivers focused on the physical requirements (loading/unloading) across the industry. This was followed by a driving simulator study which investigated "fatigue-related related decline in driving performance resulting from loading and unloading cargo," "non-duty time (rest and recovery) required to reestablish baseline fitness for duty," and "driver performance under a sustained 14 hours on/10 hours off schedule. Researchers examined driver performance over a 15-day period." Ten male CMV drivers operated a "driving simulator in simulated long-haul runs for a period of 15 days, including occasional loading/unloading sessions and a relatively high frequency of simulated crash-likely events." Performance measures and measures of subjective drowsiness were collected. In addition, participants wore wrist activity monitors to assess the amount of sleep.

Drivers were held to a schedule of 14 hours on duty (12 hours driving plus scheduled breaks) followed by 10 hours off duty. The daily driving schedule ran from simulator engine start at 0700 to shutdown at 2100. Breaks were taken on the experimental schedule and not at the subject's discretion (30-minute break at 1000, a 45-minute lunch break at 1345, and a 30-minute break at 1730). During week one of driving, half of the drivers conducted simulated loading/unloading operations for three days and no loading/unloading operations in week 2. The remaining drivers did the reverse (i.e., loaded in week 2). On loading days, drivers performed two 90 minute loading/unloading sessions during the driving day, one in the morning, and one in the afternoon.
During driving days a Psychomotor Vigilance Task (PVT) was administered 3 times (0645, 1330, 2100). Subjective examination of video records of drivers during simulated operations were conducted for samples taken from periods during which parallel indicators showed evidence of good or poor performance. Multiple measures were employed to gauge recovery, including sleep patterns, sleep latency, subjective sleepiness, and the Psychomotor Vigilance Test (PVT). These measures were repeated regularly 4 times each day (0900, 1300, 1700, 2100) during the 58-hour rest and recovery period.

The effects of loading and unloading task were mixed. There was an initial improvement in alertness; however, this effect wore off as the day progressed and may have contributed to a decrease in overall performance after 12 to 14 h of duty." "Drivers recovered baseline performance within 24-hours of the end of a driving week and should be fit to resume duty after 36 hours." "A schedule of 14 hours on duty/10 hours off duty for a 5-day week did not appear to produce cumulative fatigue."

**Relevant Findings**

- There was a gradual decline in driver response quality over time (hours at the wheel). There were slight performance degradations in the mid-afternoon, but there were improvements after each break, whether for rest, meals, or loading activities. The authors did not discuss how long the improvement effect lasted.
- The rest breaks had an influence on critical safety measures. For example, the effects of 6.5 hours of driving were reduced to starting levels by the one hour lunch break for non-loading days. While the recovery effect of a rest break is not surprising, the magnitude of the effect is striking. (Note: As the loading/unloading variable contributed to a significant interaction it is of use to examine the days when no such activity occurred, since these are more typical of the industry as a whole, and are free of the loading/unloading variance).
- After the morning physical activity, there was an improvement in driver response to crash-likely simulated situations, probably due to a short-term invigorating effect associated with physical exercise and a break in driving routine.
- The afternoon loading/unloading session did not have the same effect on drivers. Driving performance deteriorated more rapidly after the afternoon physical activity, suggesting that cumulative physical/general fatigue and time-of-day effects are sufficient to overpower some short-term effects of a change in activity. Driving performance did return to starting levels near the end of the day.
- The ability to maintain speed within posted limits and gear shifting performance both deteriorated somewhat during the latter part of the driving day. The simultaneous occurrence of the two suggests deterioration in physical coordination and vigilance late in the day, but there was no consistent linear relation to hours of driving.
- The authors note that there is "no useful way to compare the cumulative effects of the 14/10 schedule with other possible schedules (including those logically subsumed, such as 10-hour and 12-hour duty periods) because the cumulative effects for each are confounded." However, what can be said about cumulative effects is that they "appear to be nil for practical measures (e.g., probe scores) and mild for parallel subjective measures such as subjective sleepiness." Duty-day subjective sleepiness, reaction time response, and measures of driving performance showed a slight but statistically significant deterioration over the driving week, but driver response in crash-likely situations did not show cumulative deterioration. The schedule of 14 hours on duty/10 hours off duty (12 hours driving) for a 5-day week did not appear to produce significant cumulative fatigue over the 2-week testing period.
- While there was an increase in measured sleep and a decrease in sleep latency on the first off-duty rest day following the end of the driving week, the authors do not believe that the peak sleep periods during the "weekend" days were due principally to sleep

deprivation. They noted that drivers varied in the number of hours of sleep per night, and a case-by-case examination of driver sleep patterns did not show a higher rebound for those who slept less during the driving week, indicating that the variation observed did not represent deprivation. They felt that the drivers did not appear to have accumulated significant sleep loss.

- Sleep latency was measured between 2200 and 2230 on the last driving day (Friday) of each week. At this point drivers were not ready to sleep, however tired they might feel, since they had just been released from a 14-hour driving day. The second sleep latency measurement was taken between 0900 and 0930 the next morning (Saturday), shortly after the drivers had awakened from a night's sleep. The third sleep latency measurement was taken at 1300 on Saturday and proved to be dramatically the shortest sleep latency.
- Drivers returned to baseline reaction time performance and alertness within 24 hours after the end of a driving week, as shown by sleep latency, reaction time testing, and driver rating of subjective sleepiness. This effect was generally consistent across drivers. The typical recovery pattern involved extra sleep during the first rest day verified by wrist activity monitor, and an increased level of sleepiness during the afternoon of the first day (indicated by shorter sleep latency)

### *(III)4.7 Williamson, A., Feyer, A.M., Friswell, R., and Finlay-Brown, S. (2000) "Demonstration project for fatigue management programs in the road transport industry: Summary of findings."*

**Description of Study**

The aim of this project was to evaluate work-rest schedules to begin to identify some model work-rest schedules to provide companies and drivers flexibility in meeting their operational needs and to manage fatigue most effectively. The paper is a summary of findings of the results of three different reports. As this paper a summary of findings, the paper does not include a great deal of detail. The first report describes the identification of three performance measures that have demonstrated sensitivity for detecting fatigue and its effects so that they can be used in developing models of work-rest schedules. The second and third reports focus on on-road and simulated evaluations of current and alternative work-rest schedules.

The first step in this project involved a comparison of performance on a "range of performance tests under conditions in which study participants should be tired, with performance under conditions in which they had been exposed to varying doses of alcohol" to identify measures that have demonstrated sensitivity for detecting fatigue. Performance tests were administered at regular intervals over time with increasing sleep deprivation (i.e., participants were kept awake a total of 28 hrs) and increasing blood alcohol levels (BAC) (four doses of alcohol to achieve increasing BAC). The authors could then identify which tests were sensitive to increasing alcohol doses and those which were sensitive to increasing sleep deprivation.

The second and third reports focused on four evaluations, consisting of two evaluations of the current working hours regulations in New Zealand, and two evaluations of alternative approaches to work-rest schedules. All the evaluations except one (a simulation) were conducted on-road using the performance measures developed in the first step of this project. Participants started the study after being on break for 24 hours to "obtain baseline information about performance when rested”. Ratings of fatigue and performance were then taken at “strategic points across the work-rest schedule between two long 24 hour breaks.” The alternative approaches to work-rest schedules were evaluated in a simulation study and an on-road study. The simulation study looked at the extension of the daily working hours limit from a “maximum of 14 hours in a 24 hour period to up to 16 hours in a 24 hour period. The overall schedule covered 60 hours. The longer hours were balanced by beginning and ending the schedule with a 6 hour break and having a mandatory 6 hour break at some point in the intervening 48 hours. Short breaks of at least 15 minutes were also required after every 3 hours of work. The evaluation was conducted as a simulation because it had not yet been authorized to be trialed on the road as part of the pilot FMP.”

In contrast, the second evaluation of an alternative approach to work-rest schedules could be conducted on the road because “it was in operation as part of the pilot FMP.” It “differed from the regulated hours regime by allowing for longer sustained periods of work at a stretch and splitting of the mandatory breaks between them. The regulated hours allow only five continuous hours of work before drivers take a break of at least 30 minutes. In this alternative schedule, drivers could work up to six continuous hours and only needed to take breaks in 15 minute periods, although they needed to take 30 minutes in total in every six hour period. The FMP also allowed drivers to divide the mandatory six hour continuous break into shorter sections. In all other ways, the work-rest schedule was the same as the regulated regime.”

**Relevant Findings**

- While most of the tests showed deterioration in performance with increasing alcohol doses, not all the tests did so for increasing sleep deprivation.
- 0.05% BAC equivalence occurred at between 17 and 19 hours of sleep deprivation for most tests. This means that after around 17 hours of wakefulness, performance capacity was sufficiently impaired to be of concern for safety.”
- There was little evidence that current working hours led to performance decreases large enough to “constitute a significant safety risk compared to alcohol equivalent levels at 0.05% BAC.”
- In the simulation study of an alternative compliance approach, drivers were able to manage fatigue effectively over the first 16 hours of the schedule, however, their performance deteriorated significantly by the middle of the second 16 hour period. Performance at this time was “considerably poorer than the 0.05% BAC alcohol equivalence standard. It seems that the 6 hour break was insufficient to allow recovery and recuperation from the demands of the previous long day …” The work-rest schedule was “too demanding for drivers to manage fatigue effectively.”
- The results of the road test evaluation of the second alternative compliance approach showed that “reaction speed showed a deterioration across the study to levels that were suggestive of an increased safety risk based on the 0.05% BAC equivalent standard for performance”.

- Both evaluations showed, however, that performance capacity deteriorates and fatigue levels increase in relation to factors like increasing hours of work (especially night hours), short breaks and breaks that only allow short or poor quantity sleep). While fatigue and performance capacity seems to be maintained with safe limits under the regulated regime, these findings indicate that where drivers or companies take the work-rest schedules beyond the current limits, they are likely to be increasing the risk of performance decrements sufficient to compromise safety.

- Evaluation of the current working hours regime suggests that provided drivers are rested to begin with, one full cycle of the regulated regime does not produce fatigue or performance capacity decrements that of concern for safety. There is considerable evidence however that performance decrements increase significantly as the schedule becomes more demanding. This is a warning signal for the development of alternative approaches to ensure that schedules are designed that do not simply increase the demands on drivers. The evidence from both evaluations of alternative compliance schedules suggested that they increased the demands on drivers, but did not balance them sufficiently with rest in order to allow recuperation and recovery from accumulated fatigue."

- These results do not mean that the working hours regulatory regime is the only satisfactory approach to managing fatigue. The results show clearly that it is possible to increase trip length to 16 hours, say, and still maintain good performance levels. It is not possible, however, to continue to do 16 hour trips without a longer break than is usually allowed, even in the regulated regime."

***(III)4.8 Wylie, C.D. "Driver drowsiness, length of prior principal sleep periods, and naps." (1998). Transportation Development Centre. Report No. TP 13237E***

***Wylie, C.D., Shultz, T., Miller, J.C., and Mitler, M.M. (1997) "Commercial motor vehicle driver rest periods and recovery of performance."***

***Wylie, C.D., Shultz, T., Miller, J.C., Mitler, M.M., and Mackie, R.R. (1996) Commercial motor vehicle driver fatigue and alertness study." (Executive Summary & Technical Summary)***

***Mitler, M.M., Miller, J.C., Lipsitz, J.J., Walsh, J.K., and Wylie, C.D. (1997). "The sleep of long-haul truck drivers." New England Journal of Medicine, 337(11).***

***Freund, D. and Vespa, S. (1997) "U.S./Canada study of commercial motor vehicle driver fatigue and alertness". Proceedings of the XIII<sup>th</sup> World Meeting of the International Road Federation, Toronto, Ontario. June 16 – 20, 1997.***

**Description of Study**

This paper summarizes the results of an on-road study with 80 drivers in the U.S. and Canada. The goal of this study was to assess fatigue related to Canadian vs. U.S. driving schedules. Data (e.g., loss of alertness, performance, etc.) was collected on drivers for over a period of 16 weeks. Drivers drove one of four driving schedules. Time of day was the "strongest and most consistent factor influencing driver fatigue and alertness." In contrast "hours of driving (time-on-task) was not as strong or consistent predictor of observed fatigue." "There was some evidence of cumulative fatigue across days of driving."

The study used a between-subjects design involving four driving schedule conditions: C1- 10 hr daytime (5 consecutive days); C2-10 hr rotating (5 consecutive days, starting 3 hrs earlier each day); C3- 13-hr nighttime start (4 consecutive days); C4- 13-hr daytime start (4 consecutive days). The study design "was developed to comply with existing U.S. and Canadian hours-of-service regulations." "The four schedules provided different amounts of time off between trips. Condition 1 provided about 11 hours off, while the other three conditions provided about 8 hours off." Various measures were taken: driving task performance (e.g., lane tracking, steering wheel movement), driving speed and distance monitoring, performance on surrogate tests (i.e., code substitution, critical tracking test, simple response vigilance test), continuous video monitoring, physiological measures as well as driver-supplied information (e.g., daily logs, Stanford Sleepiness Scale rating).

**Relevant Findings**

- Time of day was far more important than time-on-task or cumulative number of trips in predicting driver fatigue.
- Drivers in the C3-Nighttime condition had the least amount of sleep of all the conditions.
- Night driving (e.g., from midnight to dawn) was associated with worse performance on four important criteria" (e.g., average lane tracking standard deviation, etc.).
- "There was some evidence of cumulative fatigue across days of driving. For example, performance on the Simple Response Vigilance Test declined during the last days of all four conditions."
- Drivers had approximately 2.5 hours of sleep than the amount of sleep they identified as their ideal.
- Drowsiness in Conditions C3Nighttime and C4Daystart was markedly greater during night driving.
- The observed prevalence of drowsiness formed a distinct peak about 8 hours wide, spanning late evening until dawn, and a 16-hour trough.
- There was probably greater drowsiness in Condition C2-10 rotating, trips 4 and 5, because the rotating schedule had caused these last trips, on average, to be driven through the night. Although disruption of circadian rhythms and cumulative fatigue probably contributed, time of day appeared to be a major factor.

## (III)5 TRUCK CRASH RISKS AND COSTS

### *(III)5.1 ICF Consulting and Imperial College Centre for Transportation Studies "Cost-Benefit Analysis of Road Safety Improvements" Final Report submitted to the European Commission, Brussels, Belgium, June 2003*

**Description of Study**

The European Commission (EC) was in the process of revising a number of road safety regulations primarily associated with the harmonization and enforcement of these laws through the 15 members European Union at the time. The cost-benefit study was performed to support this initiative by evaluating the benefits and corresponding costs of applying international best practices in enforcing laws relating to speeding, drunk driving seat belt use, and selected commercial vehicle safety regulations. The section of the study addressing the reformulation and enforcement of commercial vehicle hours of service and vehicle condition laws considered many of the same issues as those raised in the RIA analysis for FMCSA. Because the study relied mainly on European and other international sources, the information developed was largely independent of the sources used for this RIA analysis, and could provide another perspective on some key issues.

**Relevant Findings:**

- The fraction of truck involved fatal crashes where the truck driver was at fault in multi-vehicle was estimated at 17% by one source and 16% by another source, which also estimated that there was shared responsibility in another 14% of multi-vehicle crashes. In addition, the truck driver is at fault in the 20% of crashed that only involve a single vehicle. Taken together these results suggest the truck driver is at fault in about 36% of all truck-involved fatal crashes. In addition, one source suggested that the truck driver was at fault in a higher fraction of non-fatal crashes, up to 50%, but the data are probably less reliable.

- Of the crashes where the truck driver was at fault, the sources suggested that fatigue was a significant factor in 15-20% of all crashes, and up to 30% in fatal crashes. This leads to an estimate that fatigue is a significant factor in between 6 and 10% of all truck-involved crashes. Several sources make the observation that truck driver lifestyle off the job is a significant factor in fatigue-related crashes, and cannot be easily controlled by regulations or trucking firm managements.

- Several sources used showed that better safety management by trucking firms could have a substantial impact on crash rates, especially by raising the performance of the worst performing firms and drivers. The improvements extended beyond just HOS related crashes and could involve defensive driving techniques, better vehicle condition, better scheduling and improved pay and working conditions. Substantial reductions in crash risk, in the range 20 – 30% were cited is some example of applying such practices.

- Average per-crash costs for fatal and injury crashes were estimated at approximately 77,000 Euros, equivalent to $US 93,000. Given relatively higher medical and fatality costs applicable in the US, the corresponding cost under US conditions would be 50-100% higher.

## APPENDIX (IV) ANALYSIS OF EXEMPTIONS FOR TRUCKS OF 10,000 TO 26,000 POUNDS

The table below presents the dollar estimates of savings from the proposed rule. As the table shows, analysis of the rule, especially of the change in the log-book exemption, requires consideration of three different cases for operations under the current rule:

Case 1:driving inside the 100-mile range and choosing not to keep a log;
Case 2:driving inside the 100-mile range and choosing to keep a log; and
Case 3:driving in the 100-150 mile range, where logs now must be kept.

Safety effects of the second 16-hour day are not reported in the table or discussed further in this paper because they are expected to be very slight. On the basis of our analysis in the 2003 RIA, we estimate the increase in benefits caused by these safety effects to be well below $10 million per year.

**Summary Table**
**(Annual Savings in millions, rounded to the nearest $10 million)**

| | **Case 1** | **Case 2** | **Case 3** | **Total Annual Savings (millions)** |
|---|---|---|---|---|
| Description | Now operating within 100-mile range and not keeping logs. Duty tours ≤ 12 hours. | Now operating within 100-mile range and keeping logs. Duty tours up to 14 hours. | Now operating in 100-150 mile range. Must keep logs and observe 14-hour limit. | |
| Log-book effects | No effect: Already exempt from log requirement. Case-1 benefit: $0 | Relieved from log requirement. Case-2 benefit: $100. | Relieved from log requirement. Case-3 benefit: $40 | $140 |
| 14-hour tour with log-book exemption | May use 14-hour tour now, if they keep log. Log cost is $2.00/day. Tour>12 hours of little value to this group. Benefit: minimal | Already choosing log-book and 14-hour tour. Benefit: zero | Already have 14-hour tour. | $ 0 |

| | Case 1 | Case 2 | Case 3 | Total Annual Savings (millions) |
|---|---|---|---|---|
| Second 16-hour day | Case-1 trucks would not use the 16-hour day because they already choose not to use the 14-hour tour. Savings: $0 | Analysis is an extension of analysis of second 16-hour day that was done for the 2003 RIA. This approach did not distinguish between Cases 2 and 3. Productivity Benefit: $140 | | $140 |
| Total | | | | $280 |

***Overview of analysis***

In the 2003 RIA, ICF estimated the savings from a second 16-hour day. We have used that figure as the basis for our current estimate, adjusting for inflation and number of affected drivers. Both for the second 16-hour day and the log-book exemption, we had to estimate the number of truck-days that would be affected.

A truck-day is the relevant unit, because the magnitude of effects of both the log-book exemption and the 16-hour day depends on the number of days on which they are used. In effect, a truck-day is the same thing as a driver-day. This is based on the premise that, on any given day, each truck in use has one driver. This is virtually always the case in over-the-road trucking (except for teams); it is also the case for short-haul operations. One could imagine cases in which two different construction workers drive the same truck on the same day or one worker uses two different trucks, but we expect such cases to be rare and likely to cancel each other out.

***Details of analysis***

VIUS data:

For estimating truck-days, the starting point is the Vehicle Inventory and Use Survey (VIUS) from the 2002 Economic Census. Table 4 from the 2002 VIUS is the basis for the table in the upper left of the spreadsheet. The column headed "Trucks" gives number of 10,000 to 26,000-pound trucks (10-26 trucks) in each of the reported operating ranges. (The two columns to the left are for, respectively, medium and light-heavy trucks, the two VIUS classes that comprise 10-26 trucks.) Each truck in the survey is assigned to an operating range on the basis of respondents' statements about the range in which the truck runs the most miles. The table shows that 2,238,000 million 10-26 trucks are assigned to all operating ranges. This number is converted to truck-days for our purpose in a series of steps below the heading, "Log-book Savings." (The VIUS data may underestimate to some degree the trucks in the 101-200 range. See note at end of this paper.)

Trucks in 101-150 mile range:

We have to estimate the percentage of trucks in the 101-200 range that operate inside 150 miles. We see from the VIUS-based table that number of trucks in each range falls rapidly with each successive increment in operating range. This is clear if we consider trucks inside 100 miles and then trucks in the 101-200 range. In the first group are almost 2,000,000 trucks; in the second, 98,000. It would be unreasonable to assume that half of those 98,000 trucks are inside 150 miles and half outside, given the strong tendency towards smaller numbers at greater distances. As the spreadsheet shows, we assume that 75.0 percent of the trucks in the 101-200 range are in the 101-150 range. This leads to an estimate of 2,036,000 trucks in the 0-150 range.

Remaining steps:

Next, this number is adjusted for non-reported trucks. These are trucks included in the survey for which operating ranges were not reported. Since we need to estimate the total number of trucks in the 0-150 range, we have to add a number for non-reported trucks. We assume that non-reported trucks have the same distribution over the operating ranges as reported trucks. Therefore, we increase the 0-150 estimate by the ratio of non-reported trucks to reported trucks (373/2,238). This gives us an adjusted total of 2,375,000 trucks.

This figure must be further adjusted by subtracting trucks engaged in agriculture. For all practical purposes, these trucks can be regarded as exempt from HOS rules. VIUS reports 404,000 10-26 trucks in agricultural use. As shown, subtracting these leads to 1,971,000 trucks operating inside the 150-mile range.

One further step—adjustment for extent of use in a year—is required. Not all the trucks in VIUS are used for 12 months in a year. On the right side of the spreadsheet is a table which gives the basis for calculating truck-years according to months used. The column headed “Trucks” is for all 10-26 trucks reported in VIUS except for those with one month of use or reported as not used at all. (This column is the sum of the two columns to the left which reflect medium and light-heavy trucks, respectively.) For trucks used 7 to 11 months, we assume the average is in the middle of the range—9 months, or 75 percent of a year. This number is, thus, adjusted down by multiplying by 0.75. We do the same for 2 to 6 months of use; we assume an average of 4 months’ use and multiply by one-third. This leads to an adjusted total of 2,165,000 truck-years. We use the ratio of this number to total trucks in this table (2,165/2,534) to convert our estimate of trucks on the left side of the spreadsheet to truck-years on the basis of use. The result is 1,684,000 truck-years on the basis of actual use. This figure is the basis of our benefit estimates for both the log-book exemption and the second 16-hour day.

For the log-book savings, truck-years are converted to truck-days (driver-days) with two factors. We assume the average driver works 48 weeks a year, allowing for vacations, holidays, and sick days. On the basis of an analysis of survey data on daily and weekly hours of work for a sample of short-haul drivers, we use 5.5 days worked per week for the average short-haul driver. The next steps in the benefit calculation for the log-book exemption are in the two columns headed “Case 2” and “Case 3.” Under Case 2, the first number is 1,962,000 trucks, all the trucks in the 0-100 range from the VIUS table. This number is adjusted for non-reported trucks by the same method used for all 0-150 trucks in the column to the left—by the ratio of all non-reported trucks to the total in the VIUS table. The next step is subtraction of the agricultural trucks. We assume that all agricultural trucks are used within the 100-mile range; it would not be often that a farm truck would go 100 miles from home. This brings us to 1,885,000 trucks. This is adjusted for actual use with the factor calculated before, and we have 1,610,000 truck-years inside 100 miles.

For Case 1 drivers, who currently do not keep logs and stay within the 12-hour limit, there is a chance that some would choose to keep logs in order to be able to extend their tours beyond 12 hours. We have found, however, that any driver with a need to extend a tour even a fraction of an hour beyond the 12-hour limit would find it worthwhile to keep a log to secure that increase in productivity. We based this conclusion on the fact that keeping a log for a day imposes a cost of only about $2, whereas the increased productivity of a driver able to work another 15 minutes has a value of that same small magnitude. Cases in which drivers would choose to extend their tours of duty once the rules eliminate the log book requirement, then, would be limited to those few cases in which very short extensions were desired. Furthermore, the added savings from these cases can be shown to be quite small. Thus, we concluded that the savings from drivers in Case 1 would be minimal, and have left these savings out of the analysis.

For Case 2, we have to estimate the number of trucks operating inside 100 miles and choosing to keep logs. For this purpose, we rely on the FMCSA field survey. In the survey, 10.7 percent of short-haul trucks reported tours of duty longer than 12 hours. We assume these trucks were keeping logs; thus, we estimate that 10.7 percent of 0-100-mile trucks are using log books. With this factor, and our assumptions of 48 weeks per year and 5.5 days per week, we arrive at 44,215,000 truck-days for which a log-book would not have to be filled out under the proposed rule. We convert this to dollars with estimates from the 2003 RIA (9.5 minutes to do the log and $12.62/hour for the driver's wage) and an inflation adjustment. The result is a stream of annual savings of $95,593,000, which we have rounded to $100 million.

For Case 3, the same procedure is followed with two exceptions. First, agricultural trucks are not subtracted since they were all assigned to Case 2. Second, all Case-3 trucks are now keeping logs, so there is no need to adjust for non-log-keepers. The result is an annual stream of savings of $41,935,000, or about $40 million. The Case-2 and Case-3 benefits are summed in the column to the right for a total of about $140 million.

Benefits from the first 16-hour day were estimated in the 2003 RIA, and found to equal approximately $470 million annually. A calculation using the same methodology showed that the savings from a second 16-hour day in each week would be about ¼ as great. Thus, for 1.5 million short-haul drivers, annual savings are estimated at $118 million. This number was adjusted upwards on the basis of our truck-year estimate (1,684/1,500) and for inflation. The result is an annual savings stream of $143,307,000, which we have rounded to $140 million.

Total annual savings, including both the log book and second 16-hour days, is estimated to be about $280 million.

***Note on VIUS data on trucks in 101-200 range***

Census assigns trucks in VIUS to "primary" operating ranges according to the range in which a truck runs for most of its miles. If, for example, a respondent reports 55.0 percent of a truck's miles in the 101-200 range, that is the truck's primary operating range, and that is where the truck appears in VIUS Table 4. Obviously, that truck operates in other ranges as well. But the same would be true for a truck assigned to the 51-100 range on the basis of 50 percent of its miles. So, we would expect errors from this source to be largely self-canceling, but we cannot be sure that this is entirely so.

Some idea of the possibility for error may be found in VIUS Table 8. In this table are data on truck-miles by operating range according to what respondents actually answered. But these data are reported only for all trucks and for all except light trucks. We can, however, compare the actual reported distribution of mileage across operating ranges for this latter group to the same distribution of mileage according to primary operating range in Table 6 of VIUS. To the extent that the mileage distribution as reported comports with mileage distributed according to primary range, we can have some confidence that the distribution from Table 4 accurately represents the distribution of truck-days over the operating ranges of interest to us.

Mileage percentages for all except light trucks

| | Primary | Actual |
|---|---|---|
| 0-100 | 51.5 | 51.6 |
| 101-200 | 10.3 | 12.2 |

This suggests that our estimates based on distribution by primary range could slightly underestimate the number of truck days in the 101-150 range. On the other hand, our estimate of truck-days could be high because we have made no allowance for truck operations that may be exempted from HOS rules by State laws. Accordingly, we believe our estimate is sufficiently reliable.

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