Driving Trucking's Success

American Trucking Associations
950 N. Glebe Road, Suite 210, Arlington, VA 22203

June 8, 2011

Via email

The Honorable Anne Ferro
Administrator
Federal Motor Carrier Safety Administration
1200 New Jersey Ave., S.E.
Washington, D.C. 20590

RE: Hours of Service of Drivers - Docket Number FMCSA-2004-19608

Dear Administrator Ferro:

The purpose of this letter is to provide you with a copy of an additional document ATA has placed in the hours of service rulemaking docket. Specifically, we have submitted a paper entitled *The Good, The Bad, And The Ugly: Three Large Truck Crash Categories And What They Tell Us About Driver Fatigue,* authored by Dr. Ron Knipling. This paper is relevant in the context of further highlighting the limitations of two of the studies FMCSA recently placed on the docket on hours of service.

As you know, Dr. Knipling is exceptionally well-qualified to assess these studies and the relevance of their findings to the proposed hours of service rule. He has more than 30 years of experience in traffic safety with emphasis on driver human factors and motor carrier safety. For six years he served as the Chief of FMCSA's Research Division before accepting a position as a Senior Research Scientist and Senior Transportation Fellow with the Virginia Tech Transportation Institute (VTTI). He has authored nearly 250 technical reports, papers, and conference presentations, as well as the first and only comprehensive textbook on large truck safety, *Safety for the Long Haul; Large Truck Crash Risk, Causation, & Prevention.* In recognition of the book, he received the International Road Transport Union's (IRU) Order of Merit award, the first given to an American scientist.

As you will see, the attached paper discusses how three primary crash categories typically have distinctly different casual profiles. For instance, single vehicle crashes have the greatest likelihood of truck driver impairment or misbehavior; multivehicle crashes are more likely in dense traffic situations, of course.

This paper highlights the importance of evaluating many factors in order to effectively understand crash causation. Factors such as time of day, traffic density, and number of vehicles involved in the crash, are all critical to creating an accurate crash profile. To consider these factors, it is necessary to disaggregate the crash data. Failing to do so, according to Dr. Knipling, would be akin to "mixing apples and oranges" with respect to causal profiles.

ATA is providing this paper to further emphasize the acute need to disaggregate crash in order to understand crash cause and make appropriate policy decisions. Neither the Penn State study nor the VTTI study FMCSA recently placed in the hours of service docket do so. As a result, they merely point to crash *occurrence* but fail to draw an appropriate profile of crash *cause*. Absent a full understanding of the details surrounding the relevant crashes (e.g., time of day, single vs. multi vehicle), policy makers are simply left to make guesses about crash cause. Based on the distinctly different casual profiles of different crash categories as explained in Dr. Knipling's paper, it would be inappropriate to use such guesses as the basis for policy changes.

We trust that this paper will be read by Agency staff and very carefully considered in this process. Thank you for your time and interest.

Sincerely,

David J. Osiecki
ATA Sr. Vice President for Policy & Regulatory Affairs

Enclosure

THE GOOD, THE BAD, AND THE UGLY: THREE LARGE TRUCK CRASH CATEGORIES AND WHAT THEY TELL US ABOUT DRIVER FATIGUE

Prepared for the American Trucking Associations
June 7, 2011

Submitted to Federal Motor Carrier Safety Administration (FMCSA)
Docket FMCSA-2004-19608

Ronald R. Knipling, Ph.D.
Safety for the Long Haul Consultancy
5059 36th N. Street; Arlington, VA 22207-2946
(703) 533-2895; rknipling@verizon.net

This paper is an adaptation of research paper presented in June 2009 at the *Driving Assessment* conference (Knipling, 2009b) in Big Sky, Montana. This revision retains portions of the conference paper relevant to the overall methodology and to the specific topic of truck driver fatigue. It presents some new statistics on driver fatigue from the original research.

Summary: Large Truck Crash Causation Study (LTCCS) data are used to compare three categories of crash involvements: truck single-vehicle (SV) involvements, multi-vehicle (MV) involvements in which the truck has been assigned the critical reason (CR), and MV involvements in which the other vehicle (OV) has been assigned the CR. These three categories represent distinctly different causal contributions by truck drivers to the crash. From the perspective of the truck, OV-CR MV crashes are "good" since they are not precipitated by the truck or truck driver. Truck-CR MV crashes are "bad" since they are triggered by a truck or truck driver failure. Truck SV crashes are "ugly;" they are at-fault crashes and have the greatest likelihood of truck driver impairment and misbehavior. Factors associated with truck SV crash involvements included non-use of safety belts, driver unfamiliarity with roadways, and vehicle failures. Dense traffic situations (e.g., rush hours) make trucks more likely to be at-fault in MV crashes. Among fatigue-related factors, those related to sleep and alertness physiology were linked to SV crashes. This included lack of prior sleep, 16+ hours awake, and early morning driving. Those related only to driving and work schedules (e.g., as prescribed by daily Hours-of-Service rules) were not. This non-association was confirmed by several different types of analyses.

OBJECTIVE & METHOD

This "data mining" analysis employs statistics on crash causation, characteristics, conditions of occurrence, and associated factors from the LTCCS. The LTCCS (Starnes, 2006) employed in-depth *post hoc* investigations and reconstructions of 963 large truck crashes involving 1,123 trucks and 837 other vehicles. All LTCCS crashes resulted in one or more serious injuries; specifically, they had a police-reported severity of K, A, or B on the "KABCO" severity scale. Crashes were further selected based on a stratified sample of large truck crashes causing one or more fatalities or injuries. Cases were assigned weights to generate nationally representative statistical profiles in a manner similar to the General Estimates System. LTCCS variables provided detailed descriptions of the physical events of each crash, along with extensive information about drivers, vehicles, locations, weather, and roadways. Based on statistics in Zaloshnja and Miller (2007), LTCCS-eligible crashes represented the most severe 10.8% of police-reported large truck crashes, but because of their high severity ratings they represented 80-90% of all truck crash harm, including both human and material consequences.

This paper re-examines data from an earlier LTCCS report (Knipling and Bocanegra, 2008), which primarily compared crashes involving Combination-Unit Trucks (CTs or tractor-semitrailers) to those of Single-Unit Trucks (STs or straight trucks). The analysis examined 44 variables relating to crash characteristics, conditions of occurrence, key causal variables, and associated factors. This paper focuses on a perspective that was secondary in the original work, but which actually provided more provocative findings; that is, comparisons among different crash *categories*. In this paper, LTCCS statistics are examined for three crash categories (with their LTCCS percentage of truck involvements indicated):

- Truck SV crash involvements (26.2%).
- MV crash involvements where the truck was assigned the CR ("at-fault"; 29.1%).
- MV crash involvements where the OV was assigned the CR (43.5%).

Principal Acronyms
CR – Critical reason [≈ "at-fault"]
SV – Single-vehicle
MV – Multi-vehicle
OV – Other vehicle.

These categories represent three distinctly different causal contributions by the truck driver (or truck). SV crashes occur due to loss of vehicle control, either resulting in a road departure, rollover, or jackknife. They often involve egregious unsafe driving acts, driver impairment, or vehicle failures (Knipling, 2009a; 2009b; Dewar and Olson, 2002). Truck-CR MV crashes *can* be due to these same factors, but far more often they are due to driver information processing errors (e.g., looked but did not see) or errors in dynamic judgment (e.g., gap distances). OV-CR MV crashes represent a quasi-control condition where there was no truck driver *critical* error or other critical truck failure.

The original Knipling and Bocanegra (2008) study found few important differences between CTs and STs in their crash causal profiles or other characteristics. Far more revealing were comparisons among the three crash categories presented here. They are comparisons of crash characteristics, conditions of occurrence, and associated factors. The statistics are for aggregated CT + ST crash involvements, representing about 98% of involved LTCCS trucks. The 2% of trucks not included herein had irregular power unit and/or trailer configurations.

COMPARISONS OF CRASH TRUCK-CR PROFILES

The LTCCS *critical reason* (CR) was the immediate reason, failure, or human error leading to the crash *critical event*, which was the vehicle action or event that made the crash unavoidable. In its publications (e.g., Starnes, 2006; Blower and Campbell, 2005), FMCSA avoids the words "cause" and "fault." Nevertheless, the CR may be considered the principal proximal cause or trigger of the crash, and drivers/vehicles assigned the CR would, overwhelmingly, be legally at-fault for their crashes. Moreover, because the LTCCS recorded no causes or reasons judged to be *contributory*, the CR was the sole documented cause of LTCCS crashes. Other factors were merely *associated*, even though users are likely to draw causal inferences from them, as when "driver fatigue" is coded as an associated factor. Nevertheless, the LTCCS methodology specified that "No judgment [was] made as to whether the [associated] factors are related to the crash" (Blower and Campbell, 2005).

Table 1. Top critical reasons (CRs) for three categories of LTCCS truck crashes

Critical Reasons (includes some aggregations)	Truck SV %	Trk-CR MV %
Too fast for conditions or curve/turn**	**30% (1)**	**13% (3)**
Asleep-at-the-wheel	**13% (2)**	1%
Vehicle failure (e.g., cargo shift, brakes, tires, suspension)***	**13% (3)**	**7% (6)**
Inattention (e.g., distraction, daydreaming)*	**13% (4)**	**19% (1)**
Response execution error (e.g., overcompensation, poor control)	**8% (5)**	**3% (10)**
Heart attack or other physical impairment	**6% (6)**	2%
Inadequate surveillance (looked but did not see or didn't look)	**4% (7)**	**19% (2)**
Driver error, type unknown	**4% (8)**	**4% (8)**
Aggressive driving behavior	**2% (9)**	0.5%
Environmental factor (e.g., slick roads, weather, roadway)****	**2% (10)**	3%
Illegal maneuver	0.4%	**8% (4)**
Following too closely to respond to unexpected actions	0.4%	**8% (5)**
Misjudgment of gap or other's speed	0.2%	**5% (7)**
False assumption of other road user actions	0.0%	**3% (9)**
Other miscellaneous CRs not shown	2%	4%
Total	100%	100%

Aggregations: * Internal distraction, + external distraction, + other inattention (daydreaming), + unknown recognition error. ** Too fast for conditions to be able to respond to unexpected actions of other road users, + too fast for curve/turn. *** All vehicle factor CRs combined. **** All environmental CRs combined. Percentages are LTCCS estimates of all serious U.S. truck crashes.

Table 1 presents the top ten CRs for the two truck-CR crash categories, as well as their column percentages and top-ten ranks within each category. The 14 CRs shown encompass the top ten and at least 96% of the CRs assigned in each category. Driving too fast was the dominant CR for truck SV crashes, and high on the list for both categories of MV crashes as well. Two categories of recognition failure, inattention (encompassing several subcategories) and inadequate surveillance ("looked but did not see") were dominant in MV crashes and significant in SV crashes as well. Asleep-at-the-wheel was the proximal cause of 13% of truck SV crashes, but only 1% of truck-CR MV crashes. Heart attacks and other physical impairments presented a similar picture.

Table 1 demonstrates that truck SV and MV crashes result from largely different profiles of proximal causes. Truck SV crashes are dominated by speeding and catastrophic failures of the driver or vehicle, resulting in some form of vehicle control loss. Truck-CR MV crashes can be due to these CRs, but more often they are due to recognition failures or decision errors made in relation to other vehicles, such as a gap misjudgment or the "decision" to follow too closely. The truck-CR MV CR profile was compared to both the OV-CR MV CR profile (i.e., proximal errors made by other motorists in the crashes) and the truck SV CR profile. Table 2 shows that the profile of truck CRs in MV crashes were more similar to those of other motorists in MV crashes than they were to the truck CRs in SV crashes. Put more simply, the two types of MV crashes were more similar to each other than either were to SV crashes. This finding reinforces the qualitative causal differences between truck-CR MV crashes and truck SV crashes.

Table 2. Dyad comparisons of the three categories using two correlation methods

Correlation Method	Trk-CR MV × Trk SV	Trk-CR MV × OV-CR MV
Pearson r comparing all 34 possible specific CRs	**+0.18**	**+0.66**
Spearman rho comparing ranks of 14 top CRs	**+0.09**	**+0.46**

The fact of disparate CR profiles for truck SV and truck-CR MV crashes suggests that combining them into an "all truck-CR" category is "mixing apples and oranges." Aggregating them masks underlying crash causal profiles and mechanisms. SV-MV crash differences may not be widely appreciated, but they are not surprising given that SV crashes involve a failure of *vehicle control*, whereas MV crashes reflect primarily a failure of *response to traffic events* (Dewar and Olson, 2002; Knipling, 2009a).

CRASH PATTERNS BY TIME-OF-DAY

Crash occurrence and rates vary systematically by time-of-day (TOD). The LTCCS had no mileage or other exposure base, so only crash numbers can be shown. Exposure is far greater during the daytime and early evening hours and crash incidence TOD largely reflects this exposure difference. Two other major factors are operative. The first association is with traffic *density* on roads. For example, one recent study (Kononov et al., 2011) found that a 60% increase in freeway traffic beyond a critical density level caused an 84% increase in crash *rate* per vehicle miles traveled. The second major influence of TOD is via driver alertness. Circadian rhythms strongly affect human alertness every day. The deepest circadian trough is between 4:00am and 7:00am. Another, shallower trough occurs mid-afternoon. Figure 1 below shows smoothed incidence curves by TOD for the three truck crash categories. Crash numbers increased overall during the daytime hours, though one also sees an early morning rise for truck SV crashes. Most notably, the three curves are distinctively different, suggesting different factors at work in each.

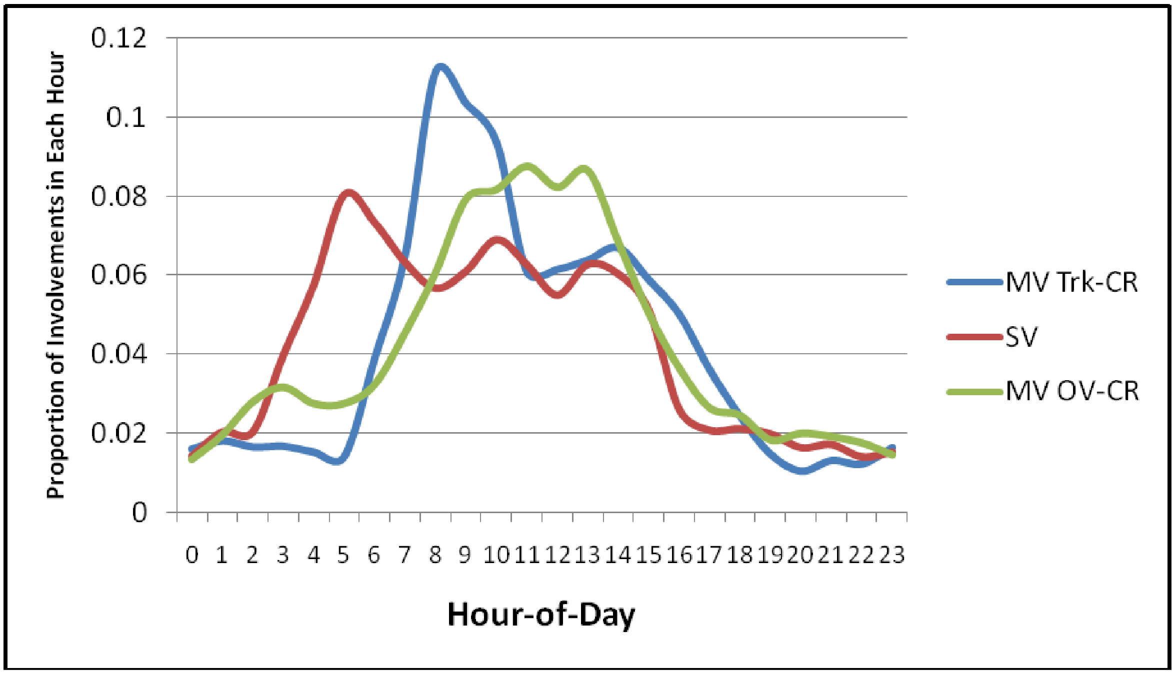

Figure 1. LTCCS crash incidence by TOD, smoothed 3-hour rolling averages

COMPARISONS OF OTHER CHARACTERISTICS

This section examines characteristics *associated* with the three crash categories. Tables 3 and 4 compare descriptions, conditions of occurrence, and other factors associated with the three categories. Each percentage is for the attribute within that variable, and coded in relation to the truck or truck driver. They are based on truck crash *involvements* rather than crashes. For example, in Table 3 truck crash involvements at freeway entrance/exit ramps were 22% of truck SV involvements, 7% of truck-CR MV involvements, and 7% of truck OV-CR MV involvements. Clearly, entrance and exit ramps are associated with truck SV involvements more than with truck MV involvements. All of the factors listed in Table 3 show this association with SV involvements; several also show greater association with truck-CR MV crashes than OV-CR MV crashes, suggesting a further association with "fault" in these crashes.

Other comparisons seen in Table 3 demonstrate that a variety of factors contribute to crash causation. Various road locations and driving situations contribute to SV crash likelihood. Safety belt non-use is not a *driving* behavior, but it is indicative of risk-related driver personality traits like "slack" risk perception and lack of conscientiousness (Eby, 2010). Driver roadway unfamiliarity (defined as having never or rarely before driven the road) is a temporary driver state affecting attention to driving. Vehicle deficiencies may affect vehicle braking or other performance, and also may be correlated with other unsafe driver or carrier practices. A recent LTCCS analysis report (Hallmark et al., 2009) corroborates many of the SV crash features shown in Table 3 and elsewhere in this paper.

Table 3. Various factors associated with SV (and perhaps MV Trk-CR) involvements

LTCCS Variable	Attribute (or Attribute Aggregation)	SV%	MV Trk-CR%	MV OV-CR%
Relation to Junction	Entrance/exit ramp related	22%	7%	7%
Trafficway Flow	Undivided (2-way w/ or w/o left turn lane) or one-way	58%	37%	36%
Posted Speed Limit	70 or 75mph	16%	6%	8%
Road Alignment	Curve (Left + Right)	60%	22%	19%
Roadway Associated Factor	Present (any deficiency)	27%	21%	17%
Pre-Event Movement	Truck negotiating a curve	46%	12%	9%
Seat Belt [Non-] Use (by Truck Driver)	None used or not indicated*	23%	8%	6%
Driver Roadway Familiarity	Truck driver rarely/never drove road before*	38%	29%	17%
Vehicle Associated Factor (Truck)	Present (any inspection deficiency)	62%	50%	21%

* % of knowns. Percentages are LTCCS estimates for all U.S. CTs + STs involved in serious crashes.

Table 4 shows associated factors more frequently seen in MV crashes, truck-CR and/or OV-CR. These factors are mostly those relating to driving in dense traffic, such as urban driving and rush hours. The incidence of other factors, including wet roads and adverse weather (statistics not shown), showed little relationship to the three crash categories.

Table 4. Various factors associated with MV involvements

LTCCS Variable	Attribute (or Attribute Aggregation)	SV%	MV Trk-CR%	MV OV-CR%
Hour-of-Day	Rush hours (7:01 to 10:00am, 4:01 to 7:00pm)	23%	44%	26%
Relation to Junction	Intersection	9%	23%	14%
Trafficway Functional Class	Urban (6 different roadway types)	38%	65%	53%
Traffic as Associated Factor	Present	6%	42%	31%
Construction/Work Zone	Present (in zone)	3%	18%	17%

COMPARISONS OF FATIGUE-RELEVANT CHARACTERISTICS

As noted in the earlier discussion of CRs, truck driver asleep-at-the-wheel is far more frequent as a proximal cause of SV crashes (13%) vs. truck-CR MV crashes (1%). Of course, truck driver asleep-at-the-wheel was never designated in OV-CR MV crashes because the CR was assigned to the other vehicle.

This section compares other fatigue-relevant crash characteristics among the three categories. These are shown below in Table 5. The first item, driver fatigue as an associated factor, was based on LTCCS investigators' evaluations of drivers' current and preceding sleep and work schedules, and a variety of other fatigue-related factors, including recreational and non-work activities. As noted earlier, factors were designated "associated" based on their *presence*; the designation did not necessarily imply a contributory role.

Table 5. Fatigue-relevant factors

LTCCS Variable	Attribute (or Aggregation)	SV%	MV Trk-CR%	MV OV-CR%
Driver Fatigue as Associated Factor	Truck driver fatigued*	30%	14%	3%
Hours of Last Sleep	< 6 hours last main sleep*	29%	15%	10%
Hours of Last Sleep	< 4 hours last main sleep*	5.9%	4.9%	4.0%
Hours Since Last Sleep	16+ Hours (as % of 0 to 18+)*	6.3%	3.5%	1.6%
Hour-of-Day	4:01 to 7:00am	24%	4%	8%
Hours Driving Since 8-Hr Break	8-10 Hours driving (as % of 0 to 10)	3.0%	7.7%	8.0%
Hours Driving Since 8-Hr Break	6-10 Hours driving (as % of 0 to 10)	22%	19%	17%
Hours On-Duty Since 8-Hr Break	12+ Hours on-duty (as % of 0 to 14+)	3.1%	2.2%	3.2%
Hours On-Duty Since 8-Hr Break	10+ Hours on-duty (as % of 0 to 14+)	6.9%	4.9%	6.6%
Hours Worked Since 8-Hr Break	12+ Hours working (as % of 0 to 14+)	2.1%	1.9%	1.6%
Hours Worked Since 8-Hr Break	10+ Hours working (as % of 0 to 14+)	5.2%	8.1%	6.4%

* Percent of knowns.

The next three items in Table 5 correspond to three well-established physiological factors underlying sleep and alertness: amount of sleep, hours since last sleep (time awake), and TOD. In a 2005 white paper, current National Transportation Safety Board (NTSB) Board Member Mark Rosekind highlighted these three factors, as follows (from Page 12):

> While there are a variety of complex factors that can affect fatigue, there are three primary physiological factors that have been scientifically demonstrated to affect

> alertness, performance and safety. These three factors are: a) sleep (specifically acute sleep loss and cumulative sleep debt), b) hours of continuous wakefulness, and c) circadian rhythms (time of day effects on sleep, alertness and performance).

The next factors listed are work schedule factors, including hours driving, hours on-duty, and hours worked. Two different attributes are provided for each; for example, driving more than 8 hours (i.e., hours 9 and 10) and driving more than 6 hours (hours 7-10). By-and-large, these factors show little relation to the three crash categories. For driving more than 8 hours (i.e., hours 9 and 10), there actually appears to be a smaller association with SV crashes than the two MV crash categories. Note that these driving- and work-related statistics are based on the legal work days at the time of the LTCCS and on data categories coded. Illegal hours are not included in this analysis because they are likely confounded by other driver and carrier risk factors present.

These LTCCS driving- and work-related findings are consistent with the view that these factors are not fundamentally related to sleep and alertness physiology. Rosekind (Page 7) stated it as follows:

> . . . while there is a large and consistent database of findings on sleep need and the effects of sleep loss, there are little to no relevant data to address work time (e.g., driving, flying) within a duty period.

One may juxtapose LTCCS data in other ways to assess whether work schedule variables affected "fault risk." For example, one can compare the overall averages of driving, on-duty, and work hours for the three categories. This is shown in Table 6. Notable are the overall low numbers (i.e., the average crash occurred relatively early in shifts) and the lack of major differences or patterns among the three crash categories.

Table 6. Average Driving, On-Duty, & Work Hours Before Crash Involvements

Variable (Range)	Truck SV	MV Trk-CR	MV OV-CR
Hours Driving (0-10)	**3.7**	**3.5**	**3.5**
Hours On-Duty (0-14+)	**4.7**	**4.1**	**4.3**
Hours Working (0-14+)	**4.3**	**4.1**	**4.3**

Another method is to compare the ratio of truck-CR involvements (i.e., truck-SV + truck-CR MV) to OV-CR involvements as a function of time. If truck driver safety performance declined as a function of driving hours and work hours, one would expect the proportion of crashes triggered by their errors to increase concomitantly. The overall LTCCS ratio of truck-CR to OV-CR involvements was 1.23 (i.e., 55.1% truck-CR/44.9 OV-CR). This proportion is higher than 1.0 because truck-CR involvements included both SV and MV crashes. The textbox shows truck-CR/OV-CR ratios for late-shift driving and work hours in comparison with those for preceding hours.

The above averages exclude crashes with unknown schedules, which were 10-20% of the dataset, depending on the variable. Nevertheless, they suggest no trend toward greater relative truck/truck driver failures precipitating crashes late in shifts.

Truck-CR to OV-CR Ratios for Different LTCCS Driving, On-Duty, & Work Periods

- Driving hours:
  - Hours 1-8: 1.27
  - Hours 9-10: 0.84
- On-duty hours:
  - Hours 1-10: 1.28
  - Hours 11-14+: 1.11
- Work hours:
  - Hours 1-10: 1.30
  - Hours 11-14+: 1.37.

SUMMARY & CONCLUSIONS

This paper has used LTCCS data (CTs + STs) to compare three categories of crash involvements: truck SV involvements, truck-CR MV involvements, and OV-CR MV involvements. It has compared crash CRs, crash occurrence by TOD, and characteristics associated with the three crash types. The focus has been on fatigue-relevant causes and factors, though other crash causes and factors have been provided for completeness and comparison. The following principal conclusions are drawn:

1. Truck SV crashes have distinctly different causal profiles than do truck-CR MV crashes. They feature more driver impairment and more choice misbehaviors like speeding. Incisive analyses of crash causes should disaggregate crashes by SV vs. MV for greater insights into causal mechanisms, and to avoid masking important differences.
2. All three crash categories are more frequent during daytime, consistent with increased exposure. Nevertheless, their frequency profiles by TOD were discernibly different, with SV crashes peaking in the early morning and the two MV crash classes peaking later.
3. Various roadway, driver, and vehicle factors are associated with truck-SV crashes more than with the two MV crash categories. Driver factors like roadway unfamiliarity and safety belt non-use had surprisingly strong associations.
4. Factors reflecting traffic interactions (e.g., rush hours, intersections) have greater associations with truck MV crash involvements.
5. Three fatigue-relevant factors with known physiological connections to sleep and alertness are also associated with truck SV involvements. This included TOD (i.e., the early morning circadian valley), lack of prior sleep, and time awake (16+ hours).
6. Schedule factors in the LTCCS had little discernible association with the three crash categories or crash "fault" in general. This included hours of driving, hours on-duty, and hours worked.
7. The average LTCCS crash occurred relatively early in work shifts; e.g., after less than four hours of driving and less than five hours of work.

This paper has employed a relative risk methodology similar to that espoused by FMCSA for analyzing the LTCCS (Blower and Campbell, 2005; Hedlund and Blower, 2006). The method does not capture *crash* risk, however. Assessing crash risk requires non-crash control or exposure data, which were not available in the LTCCS (Knipling, 2009a; Knipling et al., 2005). Rather, the current methodology assessed crash *category* risk. In spite of that important caveat, it's probable that most factors associated with *fault* in truck crashes are also associated with crash *occurrence*. Perhaps future crash investigation studies will find a way to bridge the two and thereby strengthen causal inference.

ACKNOWLEDGMENTS

The original project generating the data for this paper was funded by FMCSA and performed under a Virginia Tech Transportation Institute (VTTI) subcontract. Ralph Craft of FMCSA was the DOT project manager. Joe Bocanegra of VTTI performed the LTCCS data retrievals.

REFERENCES

Blower, D.F. and Campbell, K.L. *Methodology of the Large Truck Crash Causation Study*. Large Truck Crash Causation Study Analysis Series. Report No. FMCSA-RI-05-035. February, 2005.

Dewar, R.E. & Olson, P.L. *Human Factors in Traffic Safety*, Lawyers & Judges Publishing Company, Inc., Tucson, AZ, ISBN 0-913875-47-3, 2002.

Eby, D. "Potential Mechanisms Underlying Part-Time Belt Use,". Presentation in Session 649, TRB 89th Annual Meeting, Washington, D.C. 2010.

Hallmark, S.L., Hsu, Y-Y, Maze, T., McDonald, T., and Fitzsimmons, E. *Investigating Factors Contributing to Large Truck Crashes Using the FMCSA's LTCCS Database*. Center for Transportation Research and Education, Iowa State Univ., FMCSA report. 2009.

Hedlund, J. and Blower, D.F. *Using LTCCS Data for Statistical Analyses of Crash Risk*. Large Truck Crash Causation Study Analysis Series. Report No. FMCSA-RI-05-037. January 2006.

Knipling, R.R. *Safety for the Long Haul: Large Truck Crash Risk, Causation, & Prevention*. Arlington, VA: American Trucking Associations. 2009a

Knipling, R.R. Three large truck crash categories: what they tell us about crash causation. Proceedings of the *Driving Assessment 2009* conference, Pp. 31-37, Big Sky, Montana, June, 2009b.

Knipling, R.R. and Bocanegra, J. (2008). *Comparison of Combination-Unit Truck and Single-Unit Truck Statistics from the LTCCS*. Washington, DC: FMCSA & Volpe Center.

Knipling, R.R. Hanowski, R.J.; Hickman, J.S., Olson, R.L., Dingus, T.A. and Carroll, R.J. Exposure-risk analysis of large truck naturalistic driving data. *Proceedings of the 2005 Truck & Bus Safety & Security Symposium*, Alexandria, VA, November 14-16, 2005.

Kononov, J., Lyon, C., and Allery, B.K. Relating flow, speed and density of urban freeways to functional form of an SPF [Safety Performance Function], Paper 11-2070, *Transportation Research Board Annual Meeting*, 2011.

Rosekind, M.R. (2005). *Managing Safety, Alertness and Performance through Federal Hours-of-Service Regulations: Opportunities and Challenges*. Alertness Solutions. FMCSA rulemaking docket #FMCSA-2004-19608.

Starnes, M. (2006) *LTCCS: An Initial Overview*. NHTSA National Center for Statistics & Analysis, DOT HS 810 646, August 2006.

Zaloshnja, E. and Miller, T. *Unit Costs of Medium & Heavy Truck Crashes*. Final Report, Pacific Institute for Research & Evaluation for FMCSA, March 2007.