Research on the Safety Impacts of Speed Limiter Device Installations on Commercial Motor Vehicles: Phase II

U.S. Department of Transportation
Federal Motor Carrier Safety Administration

March 2012

FOREWORD

The purpose of this project was to identify and assess the impacts of implementing speed limiters in commercial vehicle fleet operations. These impacts may be related to safety through a reduction in the number and/or severity of crashes, and/or address operational issues.

This report is the second report of a two-phase approach. Phase I centered on a Detailed Literature Review that updated and expanded on the recent Transportation Research Board *Synthesis Report on the Safety Impacts of Speed Limiter Device Limitations on Commercial Trucks and Buses.* The Phase I Report was submitted to the Federal Motor Carrier Safety Administration in June 2009. This current study involved a series of additional tasks focused on a detailed research design and analysis, best practices applications, and identification of carrier, insurer, and enforcement official perspectives related to speed limiter implementation.

NOTICE

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FMCSA-RRR-12-006		

4. Title and Subtitle **Research on the Safety Impacts of Speed Limiter Device Installations on Commercial Motor Vehicles: Phase II Draft Final Report**	5. Report Date **March 2012**
	6. Performing Organization Code
7. Author(s) **Richard J. Hanowski, Gene Bergoffen, Jeffrey S. Hickman, Feng Guo, Dan Murray, Richard Bishop, Steve Johnson, and Matthew Camden**	8. Performing Organization Report No.
9. Performing Organization Name and Address **MaineWay Services** **PO BOX 166** **Fryeburg, ME 04037**	10. Work Unit No. (TRAIS)
	11. Contract or Grant No. **BPA DTMC 75-08-A-00001**
12. Sponsoring Agency Name and Address **U.S. Department of Transportation** **Federal Motor Carrier Safety Administration** **Office of Analysis, Research, and Technology** **1200 New Jersey Ave., SE** **Washington, DC 20590**	13. Type of Report and Period Covered **Final Report,** **February 2009–April 2012**
	14. Sponsoring Agency Code **FMCSA**

15. Supplementary Notes
The Contracting Officer's Technical Representative was Albert Alvarez of the FMCSA Research Division.

16. Abstract
The purpose of this project was to identify the impacts of implementing speed limiters (SL) in commercial vehicle fleet operations. These impacts may be related to safety through a reduction in the number and/or severity of crashes, and/or address operational issues. This report is the second report of a two-phase approach. Phase I centered on a detailed literature review that updated and expanded on the recent Transportation Research Board's *Synthesis Report on the Safety Impacts of Speed Limiter Device Limitations on Commercial Trucks and Buses.* The current study involved a series of additional tasks focused on a detailed research design and analysis, a peer review process, evaluation of speed limiter implementation, best practices applications, and identification of carrier, insurer, and enforcement official perspectives related to SL implementation.

The primary safety analysis was a focus on the reduction in truck crashes that could have been avoided and/or mitigated with an active SL installed. This was the first study to use actual truck crash data collected directly from truck fleets, representing a wide array of crashes. More specifically, the study included data from 20 truck fleets, approximately 138,000 trucks, and analyzed more than 15,000 crashes. The findings showed strong positive benefits for SLs. First, in terms of safety benefits, results indicated that trucks equipped with SLs had a significantly lower SL-relevant crash rate (approximately 50 percent) compared to trucks without SLs. Second, the cost of the technology is negligible and would not be expected to be cost-prohibitive for fleets/owners. The current study went further than any other research previously conducted in this domain and provides important data on the efficacy of SLs in reducing SL-relevant crashes.

17. Key Words	18. Distribution Statement
CMV, Commercial motor vehicle, commercial trucking, crashes, speed limiter, speed limiters	**No restrictions**

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	**Unclassified**	**94**	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized.

SI* (MODERN METRIC) CONVERSION FACTORS

Table of APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
In	Inches	25.4	Millimeters	mm
Ft	Feet	0.305	Meters	m
Yd	Yards	0.914	Meters	m
Mi	Miles	1.61	Kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
Ac	Acres	0.405	Hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME	1000 L shall be shown in m^3	
fl oz	fluid ounces	29.57	Milliliters	mL
Gal	Gallons	3.785	Liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		MASS		
Oz	Ounces	28.35	Grams	g
Lb	Pounds	0.454	Kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or “metric ton”)	Mg (or “t”)
		TEMPERATURE	Temperature is in exact degrees	
°F	Fahrenheit	5 × (F-32) ÷ 9 or (F-32) ÷ 1.8	Celsius	°C
		ILLUMINATION		
Fc	foot-candles	10.76	Lux	lx
Fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		Force and Pressure or Stress		
Lbf	Poundforce	4.45	Newtons	N
lbf/in^2	poundforce per square inch	6.89	Kilopascals	kPa

Table of APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
Mm	Millimeters	0.039	inches	in
M	Meters	3.28	feet	ft
M	Meters	1.09	yards	yd
Km	Kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
Ha	Hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	Milliliters	0.034	fluid ounces	fl oz
L	Liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
G	Grams	0.035	ounces	oz
Kg	Kilograms	2.202	pounds	lb
Mg (or “t”)	megagrams (or “metric ton”)	1.103	short tons (2000 lb)	T
		TEMPERATURE	Temperature is in exact degrees	
°C	Celsius	1.8c + 32	Fahrenheit	°F
		ILLUMINATION		
Lx	Lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		Force & Pressure Or Stress		
N	Newtons	0.225	poundforce	lbf
kPa	Kilopascals	0.145	poundforce per square inch	lbf/in^2

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003, Section 508-accessible version September 2009)

TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF FIGURES (AND FORMULAS)

LIST OF TABLES

LIST OF ABBREVIATIONS AND SYMBOLS

ANOVA	Analysis of variance
ANTC	Australian National Transport Commission
ATA	American Trucking Associations
ATRI	American Transportation Research Institute
BAC	Blood alcohol concentration
CDL	Commercial driver's license
CMV	Commercial motor vehicle
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
CV	Commercial vehicle
DTLR	Department for Transportation, Local Government, and Region
ECM	Electronic control module
ECMT	European Conference of Ministries of Transport
EMA	Engine Manufacturers Association
EPA	Environmental Protection Agency
EPROM	Erasable Programmable Read-Only Memory
FARS	Fatality Analysis Reporting System
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FOT	Field operational test
GES	General Estimates System
GHG	Greenhouse gases
GIS	Geographic Information System
GVM	Gross Vehicle Mass
IIHS	Insurance Institute for Highway Safety
ISA	Intelligent Speed Adaptation
ISD	Insufficient data

km/h	Kilometers per hour
LTCCS	Large Truck Crash Causation Study
LTL	Less-than-truckload
mi/h	Miles per hour
NHTSA	National Highway Traffic Safety Administration
NTDC	National Truck Driving Championships
OBSS	Onboard safety system
OECD	Organisation for Economic Co-operation and Development
OEM	Original equipment manufacturer
OOIDA	Owner-Operator Independent Drivers Association
QEW	Queen Elizabeth Way
RoSPA	Royal Society for the Prevention of Accidents
SEA	Safety evaluation areas
SafeStat	Safety Status Measurement System
SL	Speed limiter
SRA	Swedish Road Administration
TL	Truckload
TMA	Truck Manufacturers Association
TRB	Transportation Research Board
UMTRI	University of Michigan Transportation Research Institute
USDOT	U.S. Department of Transportation
VMT	Vehicle miles of travel
VTTI	Virginia Tech Transportation Institute

[This page intentionally left blank.]

EXECUTIVE SUMMARY

INTRODUCTION

Speeding (i.e., exceeding the speed limit or driving too fast for conditions) was a contributing factor in 8 percent of all reported large truck crashes (National Highway Traffic Safety Administration, 2009). Moreover, the Large Truck Crash Causation Study (LTCCS) reported that 22.9 percent of all large truck crashes and 10.4 percent of large truck/passenger car crashes were coded as “traveling too fast for conditions” (Federal Motor Carrier Safety Administration, 2006).

One technology used by truck fleets to lower the overall top speed of their trucks is a speed limiter (SL). SLs (also described as speed governors) are devices that interact with a truck engine to prevent trucks from exceeding a pre-programmed maximum speed. Many truck fleets use SLs to increase safety, prolong engine and brake life, and reduce tire wear.

From a safety perspective, slowing down large trucks may result in lower travel risks for all motorists on the road by possibly reducing collisions and mitigating the severity of collisions that do occur. Opponents of SLs may argue that safety can be compromised since speed-limited vehicles cannot accelerate to avoid traffic conflicts (for instance, in merging situations), and the slower speed of these vehicles relative to the surrounding traffic creates speed differentials. This argument cites studies in which speed differentials are correlated with increased crash risk.

Key takeaways from this study are:

- This study represents the most comprehensive investigation that has ever been conducted on SLs.
- The various analyses conducted used data from more than 150,000 trucks that were involved in more than 28,000 crashes.
- Results from multiple analyses indicated a profound safety benefit for trucks equipped with an active SL.
- The cost of SL technology is negligible and is a standard feature on new trucks (owners only need to activate and set the SL).
- The positive findings in this study were consistent with the bulk of the literature on this topic indicating significant safety benefits associated with speed reduction which can be achieved through the implementation of SLs. Domain research on the potential downside of speed deviations among vehicles that could occur due to the interaction of SL equipped vehicles and those without SLs seems to be far outweighed by the significant safety benefits associated with a reduction in absolute speed afforded by SLs.

PURPOSE

The purpose of this project was twofold. The purpose of Phase I was to expand on the recent Transportation Research Board's (TRB) *Synthesis Report on the Safety Impacts of Speed Limiter Device Limitations on Commercial Trucks and Buses.* Fundamentally, the Phase I literature review supplemented this TRB synthesis in order to obtain a greater understanding of the relationship between current SL research and the trucking industry, based on new regulatory initiatives and research findings since the TRB study was completed. The purpose of Phase II was to identify and assess the impacts on a motor carrier implementing SL technology in fleet operations. This task was accomplished by analyzing carrier-owned crash data and driver responses. The focus of the current study was to identify:

- Potential safety benefits, and other benefits, afforded by SLs.
- Best practices applications

Driver, carrier, insurer, and enforcement official views related to SL implementation. This document reports the results of all the tasks performed in this project.

BACKGROUND AND PROBLEM SCOPE

A literature review was performed to develop an in-depth understanding of the current state of SL use in the commercial motor vehicle (CMV) industry. This literature review revealed that the most indicative results on the effectiveness of speed limiters are from the United Kingdom (U.K.). Here, the crash involvement rate for speed-limited heavy trucks fell 26 percent between 1993 (when mandated) and 2005. U.K. authorities noted that other contributing factors may have influenced the decline, but concluded that SLs at least played a significant role. Although SLs have been mandated in Europe for more than 10 years, the literature review process did not yield any citations of empirical studies specifically assessing the safety effectiveness of SLs on long haul trucks (Transport Canada, 2008a).

Based on crash data from several studies, speeding was one of the primary factors in motor vehicle crashes; this risky behavior was also compared to driving with a blood alcohol concentration (BAC) of 0.08 (Evans, 1991). Documented disadvantages to speeding included a possible increase in transloading (Fuetsch, 2009), a higher probability of being involved in a crash (Elvik, 2004; Kloeden, Ponte, and McLean, 2001; NHTSA, 1987) and an increase in the severity of the crash (NHTSA, 1987; OECD and ECMT, 2006; Thiffaut, 2009b). Considered collectively, the literature on this topic is favorable regarding the positive benefits of SLs in reducing crashes.

The information acquired during the literature review task was used to design the current data analysis plan for developing an empirical evaluation of the effectiveness of SLs.

SPEED LIMITER IMPLEMENTATION IN COMMERCIAL TRUCKING

SLs are standard equipment on new trucks and motorcoaches and have been used for some time, with the core technology built into the Engine Control Module (ECM). Historical problems related to driver tampering have been alleviated by the current electronic systems. Because the SL capability is standard, the cost to implement SLs is negligible, although some additional costs do accrue for fleets that use external maintenance centers to change SL settings.

Safety was named as the most important benefit of SLs, for both trucks and motorcoaches. Providing drivers with an incentive for improving performance or rewarding past performance are other benefits offered to carriers through the use of SLs.

In terms of the use of SLs across the industry, there are a variety of opinions. For trucking, the Owner-Operator Independent Drivers Association (OOIDA) contends that owner-operators typically do not employ SLs. For company-owned trucks, the surveys conducted by OOIDA (2007), the American Transportation Research Institute (ATRI) study (McDonald and Brewster, 2007), and the TRB (2008) indicated that 60 to 63 percent of fleets use SLs, with variations across sectors. The investigation for this report (McDonald and Brewster, 2007) yielded much higher estimates for fleets, in the range of 75 to 80 percent. Most motorcoaches operate with SLs.

With regard to SL settings, the OOIDA (2007) survey found the preponderance of drivers operated from 101–110 kilometers per hour (ki/h) [63–68 miles per hour (mi/h)] but this survey possibly did not account for vehicles with SLs set above 68 mi/h. The Engine Manufacturers Association (EMA) and the Truck Manufacturers Association (TMA) contend that carriers set speeds at or below 113 km/h (70 mi/h). The TRB study (2008) found SL settings generally fall within the 105–111 km/h (65–69 mi/h) speed range. In the investigation for this study, SL settings ranged from 62–70 mi/h. Most commercial motorcoach fleets operate with SLs set at 116 km/h (72 mi/h); however, many motorcoach companies have settings below 113 km/h (70 mi/h).

With regard to variations in speed settings depending on driver skill or the use of cruise control, the TRB study found that approximately half of the respondents used the practice of varying speed settings, but with only minor differences for cruise control use. However, the investigation for this study found that none of the fleets interviewed utilized programs to allow qualifying drivers to drive at higher speeds.

Technology trends indicate that vehicles will eventually be “speed limit aware” based on data derived from camera and digital map data. However, it is essential that map updating techniques and robust video-based image processing algorithms be implemented and proven, to ensure that the vehicle is truly following the correct speed limit, including dynamic speed limits.

PEER REVIEW PANEL

Because the study addressed both the safety and operational cost aspects of implementing SLs, stakeholders from both of these areas were included in the Peer Review Panel designed to ensure that the research will provide valid, reliable, and useful results. Two forums that included these stakeholders were held in September: the American Trucking Associations Technology and Maintenance Council Fall Meeting and the American Trucking Associations Safety Management Council Conference. After approval of the list by the Federal Motor Carrier Safety Administration (FMCSA), 27 individuals agreed to participate and were available to attend Peer Review Panel meeting.

Discussion topics in the peer review meeting were:

- The operational definition of “speed limiter-relevant crashes.”
- Alternative data sources.
- Measures of exposure.
- Time period to include in the study.
- Representatives of the fleets used for the study.
- Driver characteristics.
- Other safety factors.
- Operational costs.
- Sample size (number of fleets and trucks).

SPEED LIMITER EFFECTIVENESS ANALYSIS METHODS

A Retrospective Cohort Approach was accepted as the most appropriate research design for the current study. Carrier-collected crash and vehicle data were gathered by the research team. Once the data were collected, trained research personnel reviewed each crash file to determine if the truck crash was an SL-relevant crash. Although the current study was similar to analyses assessing the effectiveness of onboard safety systems (OBSS), studies assessing the safety benefits of OBSSs target specific crash types that could have been prevented and/or mitigated with the systems (see Dang, 2004; Houser et al., 2009; Jermakian, 2010; Murray, Shackelford, and Houser 2009a, b). However, a truck with an active SL has many different crash types, and trucks equipped with an active SL will generally not have a crash when the truck is traveling above the preset speed (as the truck is prohibited from traveling above the preset speed unless the truck is traveling down a grade). Thus, the aim of the current study was to identify the types of crashes where an active SL would be most effective in mitigating and/or preventing high-speed [posted speed limit 97 km/h (60 mi/h) or greater] truck crashes on highways. No trucks in the SL cohort had a speed limiter setting of less than 97 km/h (60 mi/h).

Trained research personnel that were blind to the SL status of each carrier reviewed several data elements included in the crash file to determine if the crash was SL-relevant. Assessing whether a crash was SL-relevant was based on four types of information found in the dataset:

- Location of the crash [e.g., highway with speed limit $\geq$ 97 km/h (60 mi/h)].
- Crash type (e.g., rear-end truck striking).

- Contributing factor(s) in the crash (used to exclude crashes; e.g., weather-related).
- Crash narrative.

SPEED LIMITER EFFECTIVENESS RESULTS

The study collected data from 22 carriers (7 in the non-SL cohort; 15 in the SL cohort) in calendar years 2007, 2008, and 2009. Data from two carriers were not of sufficient quality to include in the analyses (i.e., it was not possible to determine the location of the crash from two carriers). Also, some carriers did not provide crash records for all 3 years; thus, the dataset was unbalanced. Because of the lack of mileage information and the unbalanced years collected by some fleets, number of trucks per year (truck-year) was used as an exposure measure. Table 1 shows the truck-years involved in one or more crashes as well as the number of crash-free trucks over the data collection period. All trucks in the study were Class 7 or 8 trucks.

Table 1. Number of Crashes and Crash-Free Trucks by SL Status

Crash Status	SL Cohort	Non-SL Cohort	Total
Truck-Years With Single Crash	13,091	2,076	15,167
Truck-Years With Multiple Crashes	520	2	522
Trucks-Year Without a Crash	111,781	10,605	122,386
Total Truck-Years	125,392	12,683	138,075

SL-RELEVANT CRASH RATE

The frequency of trucks involved in crash, crash-free trucks, and crash rate by cohort is listed in table 2. Approximately 15 percent of the crashes were identified as SL-relevant crashes (2,372 out of 15,866). This percentage falls within the observed range of truck crashes coded with speeding as contributing factor. For example, speeding (i.e., exceeding the speed limit or driving too fast for conditions) was a contributing factor in 8 percent of all reported large truck crashes (National Highway Traffic Safety Administration, 2009). Moreover, the Large Truck Crash Causation Study (LTCCS) reported that 22.9 percent of all large truck crashes and 10.4 percent of large truck/passenger car crashes were coded as “traveling too fast for conditions” (Federal Motor Carrier Safety Administration, 2006). Therefore, the assessed SL-relevant crash percentage of 15 percent determined in the current dataset seems reasonable and is in line with other nationally representative datasets, such as the General Estimates System (GES) and LTCCS.

As shown in Table 2, the overall crash rate for trucks without an SL was higher compared to trucks equipped with an SL (16.4 versus 11.0 crashes per 100 trucks/year). To further evaluate the safety effects of an SL, the SL-relevant crash rate was calculated. Similar to the overall crash rate, carriers without an SL had a much higher rate than carriers with an SL (5.0 versus 1.4 per 100 trucks/year).

Table 2. Crash Frequency and Crash Rate by SL Status

Frequency	SL Cohort	Non-SL Cohort	Total
SL-Relevant Crashes	1,736	636	2,372
Total Number of Crashes	13,786	2,080	15,866
Total Number of Truck-Years	125,392	12,683	138,075
SL-Relevant Crash Rate*	1.4	5.0	–
Overall Crash Rate*	11.0	16.4	–

*The unit for crash rate is the number of crashes per 100 trucks/year.

The mean overall crash rate and the SL-relevant crash rate across carriers and years in the SL cohort (dark red) and non-SL cohort (light red) are shown in Figure 1. Note the mean crash rate is the average of crash rates by fleet and year. The raw crash rate, as presented in Table 2, was aggregated across all fleets; thus, this approach places more weight on large fleets. The research team considered the average of fleet-year level crash as a more robust estimation. What is interesting about Figure 1 is that the overall crash rate and SL-relevant crash rate show a different pattern. However, an analysis of variance (ANOVA) found there was no significant difference in the overall crash rate when comparing the non-SL cohort (9.1 per 100 trucks/year) and the SL cohort (11.2 per 100 trucks/year; $F_{(1,45)} = 0.22$, $p = 0.645$). This is an important finding that will be highlighted later. Furthermore, an ANOVA found that the SL-relevant crash rate was significantly higher in the non-SL cohort (2.9 per 100 trucks/year) compared to the SL cohort (1.6 per 100 trucks/year; $F_{(1,45)} = 6.5$, $p = 0.014$). Note that ANOVA provides a statistical test of whether the means of several groups are all equal, and therefore generalizes the *t*-test to more than two groups. ANOVAs are helpful as multiple two-sample *t*-tests would result in an increased chance of committing a type I error. For this reason, ANOVAs are useful in comparing three or more means (Hayes, 1994). In summary, the SL cohort had a statistically significant lower SL-relevant crash rate than the non-SL cohort, but the overall crash rate between the SL cohort and the non-SL cohort did not differ statistically.

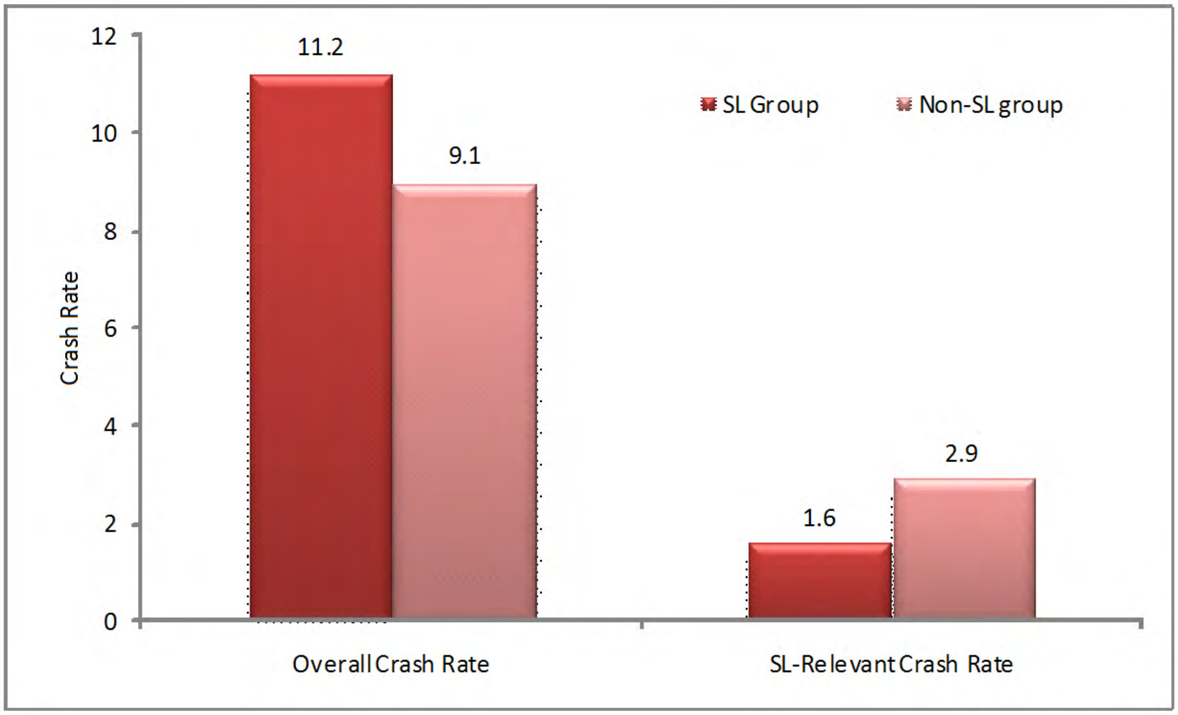

Figure 1. Chart. Average Overall Crash Rate and SL-Relevant Crash Rate in the SL and Non-SL Cohorts. Overall Crash Rate is Not Statistically Significant, and the SL-Relevant Crash Rate is Statistically Significant.

These important sets of ANOVA results were followed up with an additional analysis that would serve to either confirm or contrast these findings. To further quantitatively evaluate the safety effects of SLs, the research team used a negative binomial regression model to model the crash count, which is the state-of-practice in modeling accident frequency (Lord and Mannering, 2010). It is particularly suitable for overdispersion data where the Poisson regression model, another commonly used approach, cannot fit the data well. The model in Figure 2 is comprised of the following: let *Y subscript i subscript j* be the number of crashes for carrier *i* in the year *j*. Note that *Y subscript i subscript j* is assumed to follow a negative binomial distribution, where *mu subscript i subscript j* is the expected number of crashes for carrier *i* in year *j* and *k* is an overdispersion parameter.

$$Y_{ij} \sim \text{Negative Binomial } (\mu_{ij}, k)$$

Figure 2. Equation. Negative Binomial Regression Model.

The mean *mu* is assumed to be affected by the number of trucks in the carrier and the presence of an active SL. The model in Figure 3 is comprised of the following:

$$\log(\mu_{ij}) = \log(E_{ij}) + X_{ij}\,\beta + a_i$$

Figure 3. Equation. Log(μ_{ij}) in the Negative Binomial Regression Model.

where *E subscript i subscript j* is the number of trucks in carrier *i* in year *j* and *X subscript i subscript j* is the vector of covariate and *beta* is the regression coefficient, *alpha subscript i* is a random effect associated with carrier *i*. This model incorporated the effects of some carriers contributing multiple calendar years of data. The impacts of an active SL can be evaluated by the significance of *beta*. The exponential of *beta* is the ratio of crash rate between Non-SL cohort and SL cohort.

The model outputs are shown in Table 3 and Table 4. Table 3 provides the estimates for variance in the carrier-specific random effect and overdispersion parameter, and Table 4 provides the estimates for the effects of an active SL. The overdispersion parameter is much smaller than 1, which indicates the presence of overdispersion and is in support of the negative binomial model. Consistent with the simple ANOVA above, the presence of an SL showed a significant association with the SL-relevant crash rate ($p = 0.0295$). The estimated SL-relevant crash rate ratio was 1.94 (95 percent Confidence Interval: 1.07 to 3.49), which indicates that the SL-relevant crash rate for carriers in the non-SL cohort was twice that for the carriers in the SL cohort. Put another way, the rate for SL-relevant crashes was approximately 50 percent of the rate for trucks with an SL as compared to trucks without an SL.

Table 3. The Mixed Effect Model Covariance Parameters Estimates

Covariance Parameter	Subject	Estimate	Standard Error
Intercept	Carrier	0.2288	0.1060
Overdispersion Parameter	–	0.09642	0.03742

Table 4. The Effects of SL Status on the SL-Relevant Crash Rate

Label	Estimate	Standard Error	*P* Value	SL-Relevant Crash Rate Ratio	95% Confidence Interval
Non-SL Cohort vs. SL Cohort	0.6610	0.2875	0.0295	1.94	1.07–3.49

CONCLUSIONS

The primary safety analysis conducted in this study focused on the potential reduction in truck crashes that could have been avoided and/or mitigated with an active SL installed. This was the first study to use actual truck crash data collected directly from truck fleets, representing a wide array of truck crashes (from minor crashes involving a scrape on a mirror to fatal crashes). Specifically, the study included data from 20 trucking fleets, approximately 138,000 trucks, and analyzed more than 15,000 crashes. In addition, data were collected over a 3-year period (2007–09). The approach used in this research went far beyond any previous study in this domain.

The data used in the study were divided into two groups: trucks with an SL and trucks without an SL. The crash data were grouped into two groups as well: crashes that were SL-relevant and crashes that were not SL-relevant. Analyses included ANOVAs and data modeling (random effect negative binomial distribution). The results across analyses indicated a strong, positive safety benefit for SLs.

The ANOVA resulted in two key findings. First, there was no statistically significant difference in involvement in the overall crash rate as a function of truck type (SL vs. no-SL, $p = 0.65$). However, for SL-relevant crashes, there was a strong statistically significant difference in crash rates showing a clear benefit for trucks with a SL ($p = 0.01$). This is an important combination of findings and serves as a control of unmeasured variables that could possibly have contributed to the benefits observed for the SL cohort. As noted in the U.K. study (Transport Canada, 2008a), it is possible that contributing factors other than the presence of a SL might have influenced observed benefits. For example, it could be (and this was not measured or controlled for) that fleets with SL trucks also had in place a positive safety culture. If so, one could make the argument the positive effects observed may not have been due to the SL technology, but rather due to other safety protocols (i.e., safety culture). However, if this was the case, one would expect to see safety benefits in the overall crash rate as well in the SL-relevant crash rate. Why would safety culture, for example, only apply to certain crash types (i.e., SL-relevant)? That is, if a confounding variable such as safety culture had played a role, then the benefits (i.e., crash rate reductions) would be expected in all crash types. In addition, though not significant, the overall crash rate was in the opposite direction of what would be expected if a confounding variable, such as safety culture, had played a role. As such, the combination of these two results (i.e., a non-significant overall crash rate, but highly significant SL-relevant crash rate) supports the hypothesis that trucks equipped with SLs in the current study were effective in reducing SL-relevant crashes.

Moreover, a second confirmatory analysis was conducted whereby a random effect negative binomial distribution model was developed to model the crash count. Similar to the ANOVA results, a clear benefit was observed with this analysis approach and a significant SL-relevant crash rate reduction was found for trucks equipped with SLs (compared to non-SL trucks). The results from the modeling analysis were profound in that the resulting calculated SL-relevant crash rate ratio (1.94) was approximately twice that for non SL-equipped trucks compared to trucks with an SL.

[This page intentionally left blank.]

1. INTRODUCTION

1.1 BACKGROUND

In 2008, speeding (i.e., exceeding the speed limit or driving too fast for conditions) was a contributing factor in 8 percent of all reported large-truck crashes (National Highway Traffic Safety Administration [NHTSA], 2009). Moreover, the Large Truck Crash Causation Study (LTCCS) reported that 22.9 percent of all large truck crashes and 10.4 percent of large truck/passenger car crashes were coded as "traveling too fast for conditions" (Federal Motor Carrier Safety Administration [FMCSA], 2006). As reported by Klauer, Sudweeks, Hickman, and Neale (2006):

> *The dramatic risk of vehicle speed is illustrated by the estimated annual savings of 2,000 to 4,000 lives as a result of the nationwide reduction in the highway speed limit to 55 miles per hour (mi/h) in 1974 (Waller, 1987). When the national speed limit was later raised to 65 mi/h, the occurrence of vehicle crashes showed a marked increase (Evans, 1991). A recent analysis by Patterson, Frith, Povey, and Keall (2002) of the repeal of the National Maximum Speed Limit in 1996 supported Evans's (1991) data. Patterson et al. (2002) found that 23 States had raised their rural interstate speed limits to 70 or 75 mi/h and modeled the number of vehicular fatalities on rural interstates from 1991 to 1999 against the new speed limits in these States (i.e., 75 mi/h, 70 mi/h, or no change). Vehicular fatalities in the group of States that had raised their speed limits to 75 mi/h and 70 mi/h were higher than expected as compared to fatalities in the States that did not change their speed limits.*
>
> *Similarly, a rigorous meta-analysis conducted by Elvik, Christensen, and Amundsen (2004) included 97 different studies with a total of 460 estimates of the relationship between changes in speed and changes in the frequency of crashes or associated injuries and fatalities. Using the Power Model, this study assessed the relationship between speed and road safety. The study concluded there was a relationship between speed and the number of crashes and the severity of crashes. In fact, the data suggest that speed is likely to be the single most important determinant in the frequency of traffic fatalities; a 10 percent change in the mean speed of traffic is likely to reduce fatal traffic crashes by 34 percent and have a greater impact on traffic fatalities than a 10 percent change in traffic volume. (pg. 15–16).*

These data suggest that increases in posted speed limits increase crash risk and severity; increases in vehicle speed should also be associated with increases in crash risk and severity. This seems intuitive as "speeding reduces a driver's ability to steer safely around curves or objects in the roadway, extends the distance necessary to stop a vehicle, and increases the distance a vehicle travels while the driver reacts to a dangerous situation" (NHTSA, 2009). The impact force during a vehicle crash varies with the square of the vehicle speed, so even small increases in speed have large and potentially lethal effects on the force at impact (Roads and

Traffic Authority, 2005). This is likely to be exacerbated in large trucks given their considerable weight (more than 10,000 pounds).

1.1.1 Speed Limiters

One technology employed by truck fleets to lower the overall top speed of their trucks is a speed limiter (SL). SLs (also described as speed governors) are devices that interact with a truck engine to prevent a truck from exceeding a preprogrammed maximum speed. Many truck fleets use SLs to increase safety as well as to reduce tire wear. A synthesis on the safety impacts of SLs in commercial truck and buses found mixed support for the use of these devices in reducing crashes (Bishop et al., 2008).

1.2 OVERVIEW OF THE CURRENT REPORT

The purpose of this project was to identify and assess the impacts of implementing SLs in fleet operations on motor carriers. These impacts may be related to safety by reducing the number and severity of crashes, and/or address operational issues such as tire wear. This report is the second report of a two-phase approach. Phase I (summarized below) centered on a detailed literature review that updated and expanded on the recent TRB's *Synthesis Report on the Safety Impacts of Speed Limiter Device Limitations on Commercial Trucks and Buses* (Bishop et al., 2008). Phase II involved a series of additional tasks focused on a detailed research design and analysis, a peer review process, evaluation of SL implementation, best practices applications, and identification of carrier, insurer, and enforcement official views related to SL implementation.

1.3 SPEED LIMITER LITERATURE REVIEW

This section of the report is comprised of annotated literature review findings related to SL research and summarizes the information therein. SL applications, safety benefits, crash relationships, and research conducted thus far have been the primary focus of this review. International rulemaking for SLs in Canada, the United Kingdom (U.K.), the European Union (EU), and Australia have also been included to provide a general understanding of how the subject has been addressed by various countries (other than the United States).

Literature sources consisted of industry, academic, and government data and publications, plus direct communications with government officials in other countries. See Appendix A for the full list of organizations contacted.

The research gathered has been summarized and grouped into the following sections:

- Safety impacts of speed.
- SL regulations.
- Technologies and usage.
- Safety results from implementation.
- Other benefits attributed to SLs.

Some of the source documents were very comprehensive and addressed several of the different categories. In such cases, they are cited multiple times within the overall document as pertinent to particular sections. For the purposes of this literature review, SLs were defined as a device that connects to the vehicle's Engine Control Module (ECM) and programmed to manage travel speeds at particular settings. There are several definitions for "speeding," in the current report the term "speeding" was defined as vehicles traveling speeds in excess of the posted speed limit, as well as driving faster than what is safe for roadway conditions. For instance, environmental factors—such as adverse weather conditions—may necessitate that driver's travel at rates below the posted speeds.

1.3.1 Safety Impacts of Speed

This section of the literature review examines the literature relating vehicle speed to safety.

1.3.1.1 Speed Limit Compliance Trends

Studies of combined passenger car and truck traffic have shown that exceeding the speed limit is widespread on U.S. interstate highways (Insurance Institute for Highway Safety [IIHS], 2003). However, one study measuring truck speeds in eight different locations found that the majority of trucks were traveling within the posted speed limits (IIHS, 2008).

The U.K. Department for Transport (2007) reports that only a small number of heavy trucks exceeded the motorway posted speed limit of 97 kilometers per hour (km/h) or 60 mi/h. When the speed limit was 80 km/h (50 mi/h) on dual carriageway rural roads, and 40 mi/h on single carriageway rural roads, trucks exceeding the speed limit were 82 percent and nearly 75 percent, respectively.

Insurance Institute for Highway Safety (2008). Hit a fastball and you might score a run. Hit something in a speeding car and you might land in the hospital or worse. *Special Issue: Speed. Insurance Institute for Highway Safety, 43*.

A total of eight urban, suburban, and rural interstates were studied to determine the typical travel speed, including: Albuquerque, Atlanta, Boston, Denver, Los Angeles, Omaha, Tampa, and Washington, DC. The study was based on a limited period of observations and was not intended to definitively or comprehensively assess truck speeds. In urban areas, the vehicles were traveling in excess of posted speeds for all metropolitan locations. However, suburban and rural interstates displayed higher average speeds in only half of the locations.

Table 5 shows the proportion of trucks that were speeding and within the speed limit by location. As can be seen, the majority of trucks were traveling within the posted speed limit. Researchers concluded that, on average, trucks tended to remain at lower speeds than passenger vehicles.

Table 5. Percent of Trucks Speeding by Location

Location	Posted Speed Limit	Trucks Speeding	Trucks Within Speed Limit	Total
Urban				
Tampa	55	0%	100%	100%
Denver	55	0%	100%	100%
Omaha	60	21%	79%	100%
Suburban and Rural				
Los Angeles	75	1%	99%	100%
Tampa	70	29%	61%	100%
Intercity Segments				
Atlanta	70	5%	95%	100%
Los Angeles	55	15%	85%	100%
Washington, D.C.	65	18%	82%	100%

Insurance Institute for Highway Safety (2003). Faster travel and the price we pay. *Special Issue: Speeding. Insurance Institute for Highway Safety, 38.*

This article noted studies by the Land Transport Safety Authority of New Zealand, which examined the number of deaths associated with increased speed limits in the United States during 1995 and 1996. States that raised posted speed limits to 121 km/h [75 mi/h (from 105 km/h or 65 mi/h)] had 38 percent more deaths (per million miles) than States that did not increase posted speed limits. Similarly, States that raised limits to 113 km/h (70 mi/h) had a 35 percent increase in deaths.

When IIHS studied vehicle travel speeds in six States, findings corresponded with those of previous studies. Out of the six States, almost all had vehicles traveling in excess of 113 km/h (70 mi/h) or faster 67 percent of the time. However, Colorado had 25 percent of vehicles traveling more than 129 km/h (80 mi/h).

The report suggested that increased speeds can be attributed to a variety of factors. One explanation may be that car manufacturers are advertising faster, more powerful vehicles to appeal to the public. In addition, there do not seem to be any negative stigmas attached to speeding since it is assumed to be the accepted norm.

U.K. Department for Transport (2008). Transport Statistics Bulletin: Road Statistics 2007: Traffic Speeds and Congestion. *Transport Statistics Bulletin, 08,* 20.

This compilation of national data reported variability in vehicles exceeding posted speed limits, depending on the situation. Specifically for heavy trucks, the data showed that only a very small number of vehicles exceeded the motorway speed limit of 97 km/h (60 mi/h). When the speed limit was 80 km/h (50 mi/h) on dual carriageway rural roads, and 64 km/h (40 mi/h) on single carriageway rural roads, trucks exceeding the speed limit were 82 percent and nearly 75 percent, respectively.

1.3.1.2 Speed as a Causal Factor in Crashes

Elvik, R. (2004, November). *Speed, speed cameras and road safety evaluation research.* Paper presented at the meeting of the Royal Statistical Society.

A meta-analysis was conducted to determine the overall effect of speed reductions on the number and severity of injuries to road users. This before-and-after analysis employed the Power Model equation to compute results (Figure 4). Therefore, using the following proposed equation, a reduction of speed from 115 km/h (72 mi/h) to 105 km/h (65 mi/h) would reduce fatal accidents by an estimated 30.5 percent.

$$\frac{\text{Fatal Accidents After}}{\text{Fatal Accidents Before}} = \left(\frac{\text{Speed After}}{\text{Speed Before}}\right)$$

Figure 4. Equation. Power Model

For the meta-analysis, researchers identified a total of 174 speed-related studies. Of those, 97 contained enough information to be included in the assessment, which consisted of 460 estimates of the benefits associated with reduced speed. When the meta-analysis results were concluded, researchers noticed a slight deviation from the proposed equation. However, the findings came within reasonable expectations of the originally recommended exponent values, and the model was revised so that the incident types were counted as mutually exclusive events. Table 6 displays the revised exponent values.

Table 6. Assessment of Injury Severity Relative to Speed

Incident Type	Revised Exponent	95% Confidence Interval
Injury Severity.		
Fatalities	4.5	4.1–4.9
Seriously Injured Road User	2.4	1.6–3.2
Slightly Injured Road User	1.5	1.0–2.0
All Injured Road Users (Including Fatalities)	1.9	1.0–2.8
Accident Severity.		
Fatal Accidents	3.6	2.4–4.8
Serious Injury Accidents	2.0	0.7–3.3
Slight Injury Accidents	1.1	0.0–2.4
All Injury Accidents (Including Fatal)	1.5	0.8–2.2
Property-Damage-Only Accidents	1.0	0.0–2.0

The study concluded that the strong linear relationship between speed and road safety may be causal. This indicates that if vehicle speed is reduced, there will also be a decrease in the number of crashes and injuries. Although researchers pointed out several limitations to the study (publication bias, extraneous variables, data reliability, etc.), there was a general consensus that the limitation factors most likely did not have an effect on the results. Perhaps the most important implication noted was that speed reduction was the most critical factor related to improving traffic safety.

Patterson, T.L., Frith, W.J., Povey, L.J., and Keall, M.D. (2002). The effect of increasing rural interstate speed limits in the United States. *Traffic Injury Prevention, 3,* 316-320.

After the repeal of the National speed limit laws, many States changed their maximum speed limits on interstates. Within a year of the change, 23 States had implemented speeds of 113 km/h (70 mi/h) and 121 km/h (75 mi/h): 24–32 km/h (15–20 mi/h) above the once-required National speed limit of 55 mi/h. In order to fully understand the effect this change had on crash and fatality rates, the authors compared crash data between 1992 and 1999. The crash trends were analyzed both before the repeal (1992–95) and after (1996–99). It was determined the increased posted speed limits had a strong link to the fatality rate. For those States that increased the maximum speed to 121 km/h (75 mi/h), fatalities increased 38 percent. In States where the new limit was 113 km/h (70 mi/h), fatalities increased 70 percent. According to the authors, this connection further solidifies the argument that drivers traveling at faster speeds are more likely to be in a fatal accident.

Kloeden, C.N., Ponte, G., and McLean, A.J. (2001). *Traveling Speed and the Risk of Crash Involvement on Rural Roads.* Department of Transport and Regional Services, Australian Transport Safety Bureau, Road Accident Research Unit, Adelaide University.

In this study the relationship between vehicle speed and the likelihood of fatal crash involvement was assessed. Stipulations for study inclusion consisted of crashes that occurred in rural locations, had vehicles traveling in excess of 129 km/h (80 km/h), or resulted in at least one fatality or hospital treatment. Research team members were notified of an accident by the South Australian Ambulance Service and a total of 167 cases met the preliminary criteria for study inclusion. However, after assessing all information, the final sample consisted of 83 vehicles.

Crash reconstruction was used to determine the speeds traveled prior to the crash. Thus, speed and crash data were analyzed using a modified logistic regression formula, which examined the risk that a passenger vehicle might become involved in a fatal crash based on the speed traveled above the average travel speed. Findings implied that when traveling more than 10 km/h (6 mi/h) above the average speed, the likelihood of having a fatal crash was two-fold higher than non-crash vehicles. Interestingly, evidence indicated that vehicles traveling at slower than average speeds were less likely to have a fatal crash.

National Highway Traffic Safety Administration. (1987). *Heavy Truck Safety Study.* Report No. DOT-HS-807-109. National Highway Traffic Safety Administration, Washington, DC.

In response to a Congressional Directive, NHTSA conducted an in-depth analysis of large-truck crashes. In addition to identifying the interrelated factors that contribute to large-truck crashes, the report provided enforcement agencies with a discussion of programs that facilitate commercial motor vehicle (CMV) traffic law compliance. The report listed near-term actions that could improve heavy-truck safety as well as proposed research initiatives for long-term solutions.

NHTSA found that there were many interrelated factors that contribute to these crashes. The report identified vehicle-related factors, including braking and handling/stability, and driver-related factors (including speeding). The report found that higher speeds have a direct impact on the severity of a crash outcome. The study also found a much higher percentage of drivers involved in crashes who were exceeding a reasonable safe speed (12.8 percent) than were exceeding the posted speed limit (0.9 percent). This suggests that SLs may not address one of the top factors in large-truck crashes: traveling too fast for conditions.

Office of Motor Carrier Safety. (1999). *Analysis Brief: Speeding-Related Multi-Vehicle Fatal Crashes Involving Large Trucks.* Publication No. MCRT-00-004. Office of Motor Carrier Research and Standards, Washington, DC.

This study of fatal large-truck crashes found that up to 21 percent of large-truck crashes (n = 982) included the attribute of speeding. The study compared crashes that involved speeding to those that did not. As seen in Table 7, speeding vehicles had a higher percentage of crashes than those traveling at the posted speed limit for rural interstates, urban interstates, and urban freeways. On the contrary, crashes in which the vehicles were traveling at the posted speed limits were more likely to occur than those speeding in “rural other” and “urban other” areas.

Table 7. Distribution of Crashes by Roadway Locations

Roadway Location	Speed-Related Crashes	Crashes Within Posted Limit
Rural Interstate	18%	10%
Rural Other	47%	59%
Urban Interstate	13%	8%
Urban Freeway	5%	3%
Urban Other	17%	20%
Total	100%	100%

Federal Motor Carrier Safety Administration (2007b). *Large Truck Crash Causation Study. LTCCS Summary. Report No. FMCSA-RRA-07-017.* Federal Motor Carrier Safety Administration, Washington, DC.

This study examined the factors that increased the likelihood that a large truck would become involved in a crash. Sampling consisted of data from 963 crashes that were collected across 24 site locations in 17 States. Researchers were responsible for collecting data immediately after a crash, which consisted of interviewing persons involved, inspecting vehicles at the scene, and any documentation that might have been available at the time.

Speeding was included among the primary factors in motor vehicle crashes. Specifically, traveling too fast for conditions was the second highest factor at 23 percent; almost all of these speeding events occurred below posted speed limits. The report notes that the data presented may not be entirely representative of the population as the results were estimated from the sample data.

American Transportation Research Institute. (2009). *Speed Limiter Research.* American Transportation Research Institute, Arlington, VA.

In this study researchers collected passenger and large-truck speed data through the use of a radar gun. A total of 515 measurements were taken, accounting for 276 large trucks and 239 passenger vehicles. Findings indicated that speed differentials between passenger and large-truck vehicles were prevalent even when the posted limits were the same for both groups.

The researchers also found that, in a 121 km/h (75 mi/h) zone, trucks were compliant with the posted speed 92 percent of the time, whereas passenger vehicles were only compliant 45 percent of the time. This indicates that trucks may have a much lower speed ceiling than their passenger counterparts. Using LTCCS data, researchers examined truck-related crashes and incidents involving speeding (see Table 8). The following table shows that traveling too fast for conditions (i.e., speeding) occurred in 27.8 percent of the large-truck crashes. However, only 2.8 percent of all crashes were related to speeding in excess of the posted speed limit (exceed limit values added). This suggests that, even though nearly one-third of large-truck crashes involved traveling too fast for conditions, only 2.8 percent of the total crashes would be influenced by limiting vehicles to the posted speeds.

Table 8. Data Regarding Speeding, Speed Limits, and Crashes

Condition	Percentage
Speeding Total	**27.8%**
Exceed Limit (>5mi/h)	2.3%
Exceed Limit (≤5 mi/h)	0.4%
Not Exceed Limit	8.0%
Unknown	17.0%
No Speeding	**72.2%**
Exceed Limit (>5mi/h)	0.8%
Exceed Limit (≤5 mi/h)	1.8%
Not Exceed Limit	36.9%
Unknown	32.7%
Total	**100.0%**

National Highway Traffic Safety Administration. (2007a). *Large Truck Crash Facts.* National Highway Traffic Safety Administration, Washington, DC. Available at http://www-nrd.nhtsa.dot.gov/Pubs/811017.PDF.

In 2007, for the first time in more than 10 years, the total number of fatalities for all vehicle types declined to a level that has not been seen since 1994. Since 2006, there has been a reduction in fatalities by 3.9 percent—a record low since 1992. Passenger-vehicle fatalities have been decreasing over the past 5 years, whereas light trucks fatalities have had the same rate for 2 consecutive years. Interestingly, the fatality rate of all vehicles per 100 million vehicle miles of travel (VMT) has continued to decline despite the fact that VMT has also decreased (from 2006 to 2007).

Evans, L. (1991). *Traffic Safety and the Driver.* Van Nostrand Reinhold, New York, NY.

This research effort conducted an in-depth analysis of traffic safety data and the factors underlying the crashes. The author recounted the dramatic decline in drunk driving and attributed at least some of this decline to the fact that drunk driving has become socially unacceptable.

However, the author noted a lack of social pressure to reduce other harmful driving practices, such as speeding.

The author correlated drivers traveling 105 km/h (65 mi/h) in an 89 km/h (55 mi/h) zone to an increase in the risk of involvement in a fatal crash. This risky behavior was cited as being similar to that of a driver with a blood alcohol concentration (BAC) of 0.08 percent. Evans suggested that post-crash alcohol testing provides key evidence of impaired driving, but measurements of speed and the role speeding plays in crashes are less reliable. This results in a lack of data documenting speeding as a causal factor; thus, the role of speeding as a factor in crashes was significantly underestimated. Lastly, Evans noted that speed is a central component in helping to reduce the risk of a crash.

Hickman, J.S., Knipling, R.R., Olson, R.L., Fumero, M.C., Blanco, M., and Hanowski, R.L. (2005). *Phase I: Preliminary Analysis of Data Collected in the Drowsy Driver Warning System Field Operational Test.* Contract No. DTNH22-00-C-07007, Task Order No. 21. Federal Motor Carrier Safety Administration, Washington, DC.

NHTSA and FMCSA funded a field operational test (FOT) of a drowsy driver warning system. The study included 103 drivers and 43 trucks. The FOT collected data, via onboard safety systems and multiple cameras, and evaluated the effectiveness and limitations of a driver drowsiness monitoring system. The study found that minimizing driver internal distractions and increasing defensive driving techniques were essential. The study reported that the top contributing factors in crashes were inattentive/distracted drivers (35.7 percent), apparent unfamiliarity with the roadway (28.6 percent), and drowsy/asleep (21.4 percent). These findings suggest that, although SLs will likely not mitigate two of the top three contributing factors (inattentive/distracted drivers and drowsy/asleep drivers); SLs could play a role in reducing crashes that occur when a driver is unfamiliar with a roadway. This would apply to situations in which the driver is exceeding the posted speed limit, but not in cases where the driver is driving too fast for conditions. SLs may also reduce the frequency of crashes involving inadequate evasive action (14.1 percent). However, the efficacy of SLs in reducing these incidents is predicated upon whether or not the driver is exceeding the posted speed limits or traveling too fast for conditions.

Organisation for Economic Co-Operation and Development and European Conference of Ministries of Transport (2006). *Transportation Research Centre: Speed Management.* ISBN 92-821-0377-3. Organisation for Economic Co-Operation and Development (OECD) and European Conference of Ministries of Transport (ECMT).

This report provided perspectives and recommendations regarding speeding and speed management based on the joint efforts of representatives from several OECD countries. Although traveling at greater speeds may provide some benefits for decreasing the amount of time to deliver goods, the time saved may not be that substantial for shorter distances and can pose safety threats. Reaction times, information processing, and actions taken to respond to driving situations while speeding are factors that can have detrimental effects on crash likelihood as the time to react and stop a vehicle increases dramatically as speed rises. When speeding and poor roadway conditions (such as wet pavement) are combined, stopping distance is delayed by an additional 25 percent.

There have been many factors identified that contribute to the probability of being involved in a crash. One finding suggests that the difference in speed between cars and trucks can have a significant negative impact on crash rates. As the differences in speed increase between vehicles, an adverse event becomes increasingly plausible, based on crash exposure. Also, crashes that do occur tend to be more severe when speeding has been involved. Furthermore, crash severity has been shown to be dependent on the mass difference of vehicles involved—where large truck mass can be up to 20 times greater than cars, signaling a safety concern.

The report addressed the impact of speed variance on crashes. The authors note that speed variance is particularly important in urban areas, given the mix of different types of motorized users with non-motorized users. The issue also arises for highways on steep hills (both up and down hills), where the speed differential between passenger cars and trucks can be large. The report notes that when differences in speed were large, passing maneuvers increase, thereby, increasing crash risk. Further, such speed dispersion is strongly related to road fatalities on interstate highways, rural roads, and arterials.

This report's discussion of speed dispersion highlights the many dimensions of this issue. Research on speed dispersion must be carefully examined to determine if it applies to the relatively small speed differences that occur between speed-limited trucks and those exceeding the posted speed limit.

The authors believed speed management should be part of any national road safety strategy, as a means of achieving policy goals for safety as well as mobility and environmental benefits. They assert this should be coupled with analyses to set appropriate speed limits for all types of roads, based on crash risk and other factors such as presence of vulnerable road users and roadside characteristics. Their recommendations are bolstered by the successes achieved in three countries due to changes in posted speed limits and enforcement strategies. Starting in 2002, France adopted an enforcement strategy which included both a strong focus on speed enforcement and the introduction of automatic enforcement. Over the course of 3 years, the average speed on French roads decreased by 5 km/h (3 mi/h) and fatalities decreased by more than 30 percent. Also in 2002, the Australian state of Victoria launched their *Arrive Alive!* Strategy, which included an initiative to reduce vehicle speeds via increased enforcement. Decreases in the average speed were observed, especially in 60, 70 and 80 km/h zones (37, 44, and 50 mi/h), resulting in a 16 percent reduction in fatalities in 2005 as compared to 2002. A 43 percent reduction in fatalities also occurred in metropolitan Melbourne from 2001 to 2003. The authors note that it is difficult to attribute these reductions solely to speed factors; however, the role of reduced speed is at least suggestive. In Hungary, the speed limit within urban areas was reduced from 60 km/h to 50 km/h in 1993, and resulted in a reduction of 18.2 percent in crash fatalities in the following year.

Thiffault, P. (2009b). *SPEED: Section 1: Speed and safety (first draft).* Currently unpublished. Transport Canada, Ottawa, Canada.

Based on a broad literature review, the author concluded that the relationship between speed and safety hinges on four key points: speed diminishes the ability to drive safely, speed is a major contributor in crashes, speed factors interact with crash rates in a variety of ways, and speed has a severe impact on crash severity.

It was concluded that speed contributes to crashes; however the evidence is multifaceted and complex. The report cites a range of studies to conclude that speed and speed dispersion are associated with crash involvement in the following ways: crash risk is lower near the average speed and higher for vehicles traveling much faster and much slower, and crash probability and severity increases with speeds that are higher than the surrounding traffic flow.

The author concluded that absolute speed is more important than speed variance. First, there are common crash types in which the consequences are not related to speed variance, such as single-vehicle and head-on crashes. Secondly, absolute speed affects the time available for a driver to handle an impending crash situation, as well as the energy in a crash which does occur. The author refers to literature which notes that when speed variance is decreased by having the slower drivers drive faster, there is an increase in mean speed and an increase in crashes; only when reduction of speed variance is brought about by reductions in mean speed does crash rate decrease.

1.3.2 Speed Limiter Regulations

This section examines policy and regulatory issues relating to SLs in different countries.

1.3.2.1 Australia

Australian National Transport Commission (2008). *Sharing Responsibility for Heavy Vehicle Speed Compliance.* Available at http://www.ntc.gov.au/NewsDetail.aspx?newsid=252.

The article notes that "Chain of Responsibility" laws that target the cause of heavy-vehicle speeding have been approved unanimously by the Australian National Transport Council (ANTC). According to the ANTC, the focus of the new laws is on the underlying cause of heavy-vehicle speeding—shippers and other off-road parties in the logistics chain whose delivery schedules and deadlines put pressure on drivers to break road laws. Overall, the intention is to create a culture where speeding is not tolerated.

Chain of Responsibility reforms agreed on by Transport Ministers now cover heavy-vehicle overloading, driver fatigue, and speed offenses. The article notes that all state governments have agreed to implement the model Chain of Responsibility laws for speed compliance within 12 months. Out-of-compliance penalties include court-imposed corporate fines of up to $50,000 plus three times the estimated commercial benefit gained by breaking the law.

Ballingall, S. (2007). Speed Limiters on Heavy Vehicles in Victoria, Australia. Email Correspondence. VicRoads Vehicle Safety Department.

SLs are defined in Australian Design Rule 65 as devices which limit the maximum speed of a vehicle. The rule requires all heavy trucks greater than 12 tons gross vehicle mass (GVM) and all buses greater than 5 tons GVM to be fitted with an SL (to be set to limit the maximum speed by deceleration to no more than 100 km/h or 62 mi/h). The author notes that speed-limited vehicles can travel faster than the speed to which the limiter is set—in excess of 15 km/h (9 mi/h) above the speed-limited speed if going downhill when at or near maximum legal vehicle mass. The author notes that SL tampering is a major concern. At the time of this writing, ways to make SLs more tamper proof and/or tamper evident were being examined.

Australian National Transport Commission (2006). *Heavy Vehicle Speed Compliance: Draft Proposal and Draft Regulatory Impact Statement*. Australian National Transport Commission, Melbourne, Australia.

The Australian Design Rule 65, introduced in July 1990, mandated that large trucks and buses be fitted with an SL set to a maximum speed of no more than 100 km/h. To further improve safety, the ANTC adopted the National Vehicle Safety Strategy 2003–10 in an effort to reduce injuries and fatalities caused by large-truck crashes. One of the objectives of the Strategy is better speed management and recognition that heavy-vehicle speed compliance is only one of the factors in safety-based outcomes. In 2005, the ANTC conducted a review of large-truck compliance with posted speed limits and evaluated several regulatory proposals. Based on these economic analyses, the ANTC proposed regulatory mechanisms that best improves safety-based outcomes.

The proposed approach, with the most positive benefit-cost ratio, is based on the development of a "chain of responsibility for speed compliance." This approach places at least some responsibility on all supply chain stakeholders that may influence whether or not speeding occurs. In essence, these stakeholders must ensure that the driver is not required to speed to complete a road transport task. The report estimates that 10 to 30 percent of SLs have been tampered with, and that 100 percent compliance by large trucks with SLs would result in 29 percent fewer large-truck crashes.

1.3.2.2 Canada

Transport Canada sponsored a series of studies in 2007–08 that can be considered the most significant body of work recently published on the topic of SLs. The Transport Canada (2008d) Summary Report is their summary of the results of this multidimensional set of studies. The studies addressed safety implications, international factors, technical considerations, trade and competitiveness impacts, and environmental benefits. Also, a case study was performed involving key motor carriers. The detailed safety-relevant results of these studies are covered below in the section titled "Safety Results from Implementation." In January 2009, SLs became mandatory in CMVs in the Canadian provinces of Ontario and Quebec. The laws require that trucks be governed at a maximum speed of 105 km/h.

Transport Canada (2008d). *Summary Report: Assessment of a Heavy Truck Speed Limiter Requirement in Canada.* Transport Canada No. TP-14808. Transport Canada: Ottawa, Canada.

This report is Transport Canada's summary of the results of a multidimensional set of studies conducted during 2007–08. The focus of these studies is summarized here, with pertinent results summarized in later sections. A Safety Implications Study was conducted to determine whether SLs would reduce the risk and severity of crashes for trucks. The study assessed the safety impact of speed differentials and car-truck interactions in a speed-limited environment. Traffic simulations for three highway scenarios were conducted for the study as well as a case study of a freeway section in the Toronto area. An international assessment examined the experiences in three countries (Australia, Sweden, and the United Kingdom) with SL legislation in place.

The International Assessment noted the importance of a consistent national approach to SL compliance, based on comments from stakeholders interviewed. There exists a tension between consistency and legislative flexibility at the state level (across Australia) and the national level (across Europe). The European requirement provides this consistency across European Union (EU) Member States (i.e., that the SL must be set at 90 km/h for all trucks greater than 12 tons). In the case of Australia and Sweden, regulations and policies proposed at the national level are not always adopted at the state, territorial, or county level and this has led to inconsistencies in regulatory approaches toward enforcement and compliance.

A case study involving two large Canadian carriers was conducted to document the benefits and experience of SL usage within the Canadian trucking industry. Both firms, representing the for-hire and private trucking sectors, have operated with SLs since the mid 1990s. They believe SLs have had a significant positive impact on safety and maintenance costs.

A Technical Considerations Assessment summarized technical issues and limitations of electronic SLs with respect to compliance, enforcement, and tampering. The summary was based on survey responses from truck and engine manufacturers. Other studies examined trade and competitiveness impacts and environmental benefits.

Fuetsch, M. (2009). Soft enforcement of limiters underway for all truck drivers in Ontario, Quebec. *Transport Topics, 3828,* 2.

SL laws for CMVs took effect in January 2009 in the Canadian provinces of Ontario and Quebec. The laws require that trucks must be governed for a maximum speed of 105 km/h (slightly over 65 mi/h). In the first six months, law enforcement agencies conducted “soft enforcement,” with an emphasis on stopping drivers and reading SL settings, rather than issuing citations for non-governed or inadequately governed trucks. Enforcement will check SL settings primarily at weigh stations and public officials estimate 2 to 5 minutes will be added to inspection times. The law requires that trucks hauling freight bound for either province must use limiters with the properly set maximum speed or relinquish freight at the border. A segment of the industry believes the law will increase “transloading” of freight at the provincial borders from non-governed trucks to those with governors.

Supporters of the SL law cite two primary benefits: safety improvements and better fuel economy (thereby reducing greenhouse gas [GHG] emissions). However, the industry remains divided over the law. The Owner-Operated Independent Drivers Association (OOIDA) continues to oppose the law, citing concerns over its benefits, the training for law enforcement, and the need for equipment to access limiter settings via the engine control module. Conversely, another segment of the industry sees little or no impact to operations due to existing SL settings already at or below the mandated maximum speed. These carriers note that adoption of these lower settings improve safety and increase fuel economy.

American Trucking Associations. (2008). Ontario Ministry of Transportation Carrier and Enforcement Branch Proposed Regulations on Speed Limiters. American Trucking Associations, Arlington, VA.

The American Trucking Associations (ATA) recently advocated for the use of SLs within the United States to increase highway safety for users. The specific petition suggested that NHTSA and FMCSA proceed with rulemaking for the use of SLs in the United States. In the request, vehicle manufacturers would be required to set speeds at no more than 109 km/h (68 mi/h) on newer trucks and any adjustments to the devices would be prohibited.

Although Ontario's vision is generally supported, there were a few recommendations to consider prior to implementing the rulemaking:

- Newer CMVs would fall under the SL requirement since older vehicles might lack the technology to install the systems properly.
- Original Equipment Manufacturers (OEM) would have the final say in what qualifies as a speed-limiting system since methods to install the device would differ across manufacturers.
- Elimination of the requirement that a device is only functioning properly if the system prevents the vehicle from traveling more than 105 km/h (65 mi/h) on level ground.
- A threshold of 10 percent would be allowed to compensate for environmental factors that may temporarily cause a vehicle to travel faster than the set limit.
- All CMVs should be included in the proposed action, with the exception of emergency vehicles.
- Vehicle control modules would reflect the accurate settings at the time of manufacture to prevent minor speed variations that may occur with maintenance, tire size, and other factors.

Gillam, T. (2006). Ontario, Quebec plans advance to impose truck speed limiters. *Transport Topics, 3696,* 30-31.

Prior to the adoption of SL laws in Ontario and Quebec, the industry remained divided over the use and efficacy of limiters to achieve the purported benefits of improving safety. Proponents of the bill cite improved CMV safety by reducing both the number and severity of large-truck crashes. Opponents of mandated SLs opined that reducing the speed of CMVs, and not automobiles, would adversely impact safety as the interaction between CMVs and automobiles increases. In addition, the industry remains concerned over how enforcement and regulation will be conducted as well as the proliferation of disparate provincial-level regulations.

Canadian Trucking Alliance (2006). News Release: Canadian Trucking Alliance Wants to Put the Brakes on Speeding Trucks. For Release on March 2, 2006.

As an active representative of more than 4,500 trucking companies, the Canadian Trucking Alliance focuses on increasing safety among roadway users. In 2006, the organization endorsed a national policy that would require SLs on all trucks. Maximum speeds would be set to 105 km/h (65 mi/h). The laws would affect Canadian trucks and those entering the country as well. The primary benefits associated with the devices would include: fuel savings, reduced GHG emissions, fewer severe crashes, improved lane discipline, and a decrease in tailgating.

1.3.2.3 Europe

Royal Society for the Prevention of Accidents. (2001). Response to the DTLR's Invitation to Comment on the European Commission Proposals for Speed Limiters on Commercial Vehicles. Royal Society for the Prevention of Accidents, Birmingham, U.K.

The Royal Society for the Prevention of Accidents (RoSPA) accepted the request to comment on the Department for Transportation, Local Government and Region's (DTLR) proposal and suggested that there is a need to study the effectiveness of top SLs in order to fully understand any safety relationships. As a result of the limited research conducted, there has not been any information linking the safety benefits of SLs to light trucks, buses, coaches, midi-coaches or minibuses. Therefore, RoSPA did not believe that the proposed measures would have a substantial effect on reducing roadway casualties. The real issue may be related to driving at inappropriate speeds within lower posted limits, which SLs do not address. Ultimately, RoSPA advocates for more long-term goals in which all vehicles would be equipped with intelligent SLs.

Organisation for Economic Co-Operation and Development and European Conference of Ministries of Transport. (2006). *Transportation Research Centre: Speed Management.* ISBN 92-821-0377-3. Organisation for Economic Co-Operation and Development (OECD) and European Conference of Ministries of Transport (ECMT).

This report summarizes EC Directive (92/24/ECE) on SLs, which originally required SLs on trucks greater than 12 tons and buses manufactured after 1987 (with the specified limits 90 and 100 km/h, respectively). The Directive was since extended to apply to light CMVs greater than 3.5 tons and passenger vehicles with more than nine seats (ECE 2004/11). The report cites research supporting the regulation, which showed positive effects on emissions and fuel consumption through the prevention of speeding.

The EC Directive requires SLs to be generally resistant to tampering and not to be adjustable while the vehicle is in motion. However, the illegal modification of SLs to allow higher speeds continues to be a problem. This study recommended that, in countries with no such mandatory system, consideration should be given to mandatory SLs for trucks and motorcoaches. However, they noted that even such limitations would not solve all the speed problems, especially in urban areas, where limitations on maximum vehicle speed would not affect compliance with lower speed limits.

Repussard, J-P. (2007). Study on speed limiters. Email Correspondence. European Commission Directorate General Energy and Transport, Unit E3-Road Safety.

Mr. Repussard confirmed that the first EU legislation in this area was adopted in 1992 (for bigger vehicles) and then, in 2002, it was extended to smaller vehicles. There is now a single standard for all trucks weighing a minimum of 3.5 tons and motorcoaches that contain at least nine seats. The author notes that the legislative text speaks to road safety and environmental issues almost equally (as a likely after-effect of the energy shortages of the late 1970s). The author also confirmed that an EC Directive such as this requires that each EU Member State must pass a national law implementing the terms of the Directive.

1.3.2.4 United States

Johnston, J., and Shapiro, C. (2007). *Comments in Response to Notice and Request for Comments, Motor Vehicle and Carrier Safety Standards.* Docket No. NHTSA-2007-26851. Owner-Operators Independent Drivers Association, Grain Valley, MO.

The authors submitted comments on behalf of OOIDA in a response to NHTSA and FMCSA petitions for a rulemaking by ATA, Road Safe America (a safety advocacy group), and a group of nine motor carriers. The rule would require the use of SLs on certain CMVs with a maximum speed of 109 km/h (68 mi/h) and prevent tampering with or adjusting these set speeds. OOIDA argued that the mandated use of SLs would decrease safety since the interaction between large trucks and automobiles would be increased. The authors noted that research has shown that automobile/light-truck drivers are more likely than CMV drivers to engage in unsafe driving behaviors, such as traveling at excessive speeds. Based on this research, the authors predicted more traffic crashes, namely entrance/exit ramp collisions, cars rear-ending trucks, and sideswipe crashes. In addition, the authors argued that an SL mandate would not address one of the top causes of large truck crashes: traveling too fast for conditions.

Insurance Institute for Highway Safety (2007a). Good news about teen drivers. *Insurance Institute for Highway Safety Status Report, 42.*

Recognizing the ongoing issues of large-truck crashes in which speed was a factor, some truck drivers, trucking companies, and industry representatives are pressuring FMCSA to require SLs. According to the 2007 survey of passenger-vehicle drivers, 80 percent noted that speeding was a safety issue and 64 percent agreed that SLs, set below 113 km/h (70 mi/h), were necessary. Many trucking companies currently limit the maximum speed of trucks without the restrictions of an FMCSA regulation. When purchasing new trucks, some carriers have speed limits set by the manufacturer prior to delivery. According to ATA, which also supports SLs, having this policy in place not only improves safety for the motoring public, but reduces maintenance, fuel use and emissions, and extends the life of truck tires.

Insurance Institute for Highway Safety (2007b). *Devices to Limit the Speed of Certain Trucks Request for Comments.* Docket No. NHTSA-2007-26851. U.S. Department of Transportation, Washington, DC.

In a memo to the administrators of FMCSA and NHTSA, the IIHS provided an argument in support of the implementation of SLs set at 109 km/h (68 mi/h). The primary objective of the document was to provide a solution to the number of fatal crashes involving trucks with other vehicles. According to the document, speed has a role in 23 percent of truck crashes. In addition, those with one or more speeding convictions within the past 3 years were involved in 24 percent of fatal crashes in 2005. Therefore, reducing the speed of trucks would reduce the crash rate.

The IIHS also provides other motivating reasons to implement SLs, including a reduction in fuel use and public support. The authors also cited the lack of law enforcement resources to adopt speed cameras or monitor roadways where speed is an issue. Although the memo stated that 68 mi/h is a valid speed limit for the devices, it also concluded that it is only a starting point and should be further reduced in the future.

American Trucking Associations. (2009). *Expanding ATA's Safety Agenda: Executive Summary.* American Trucking Associations, Arlington, VA.

According to ATA's 2009 safety policy, all class 7 and 8 large trucks manufactured after 1992 should be equipped with SLs set at 105 km/h (65 mi/h). This ATA policy was first addressed in a petition to NHTSA in which ATA stated that class 7 and 8 trucks should be limited to 109 km/h (68 mi/h). As a complement to this policy, ATA also recommended that the SLs be tamper-resistant. Since then, the topic has been studied by Congress, but a bill has not been drafted.

1.3.3 Speed Limiter Technology and Usage

This section examines reports discussing FOTs with speed-limiting technology, as well as motor carrier usage of SLs.

1.3.3.1 Intelligent Speed Adaptation

Intelligent speed adaptation (ISA) either advises drivers or intervenes to maintain the prevailing posted speed limit. Empirical studies, such as FOTs, for speed-limiting technologies have been conducted with passenger cars to evaluate ISA. Although significant safety benefits have been estimated for broad ISA implementation, driver acceptance in the FOTs was mixed (Bishop, 2005; Comte et al., 2000; Svedlund, 2002).

The OECD and ECMT (2006) were quite supportive of continuing down the path of ISA implementation, if shown to be cost-effective; with voluntary SLs at the initial roll-out, and potentially mandatory devices in the longer term. Despite the substantial activity in this domain, ISA is motivated by a desire to increase safety on urban, arterial, and residential roads, and therefore is not directly relevant to the domain of motor carriers operating on major highways.

Bishop, R. (2005). *Intelligent Vehicle Technology and Trends.* Artech House, Norwood, Mass.

This book provides an overview of current intelligent vehicle technologies and active safety systems worldwide, including ISA. ISA is a system that maintains awareness of the current posted speed limit and provides a driver with "insistent" feedback when the driver is exceeding the posted speed limit. Most ISA work has focused on passenger cars, to moderate speeds in urban and residential areas. The book reported the results of a study which found that drivers would support use of the system if it reduced large speeding fines.

Three case studies are detailed. In Sweden, the author found the ISA system reduced speed violations and did not lengthen travel times. In addition, it was projected that if all vehicles were equipped with an ISA, crashes would decline by 20 percent. A second case study (conducted in France) found that, although drivers supported the concept of an ISA, less than one-third of drivers actually favored an ISA in their vehicle. In reviewing the results of another case study, the author noted that researchers estimated that a dynamic SL system/ISA could reduce injury crashes by 36 percent and fatal crashes by 58 percent. However, the author also noted that CMV operations are very different from automobile operations; thus, an ISA system may not be relevant to CMV operators that travel primarily on interstate roadways.

Comte, S., Wardman, M., and Whelan, G. (2000). Drivers' acceptance of automatic speed limiters: Implications for policy and implementation. *Transport Policy, 7,* 259-267.

This research detailed the results of a survey of automobile drivers' perceptions and opinions on the use of SLs. The study made an effort to identify the components of an SL program that most facilitates drivers' acceptability. Survey respondents indicated that enforcement was more appropriate than SLs for targeting drivers that exceeded the posted speed limit. However, respondents also indicated a belief that enforcement was both expensive and ineffective and that SLs were the best option for discouraging excessive speeds. The authors conclude that, although respondents believe SLs may discourage excessive speed, drivers remain concerned over potential impacts on comfort and safety.

Svedlund, J. (2002). ISA in daily life. *Proceedings of the ITS World Congress.* Beijing, China.

In an article published by the Swedish Road Administration (SRA), the use and acceptance of ISA by both passenger and CMV drivers was evaluated. Between the years 1998 and 2002, Sweden held an assessment of ISA implementation strategies. During this period, 1,000 systems were installed. It was determined that many objections exist that prevent drivers from purchasing the technology. However, the list of benefits outlined in the report is extensive, including:

- Savings in fuel and maintenance costs.
- Reducing speed-related crashes.
- Straightforward integration with other technologies already in use.
- Competitiveness within the industry.

In addition, the SRA stated that working with other safety stakeholders, as well as drivers, could further promote the widespread use of ISA throughout Sweden and improve accident rates.

Varhelyi, A. and Makinen, T. (2001). The effects of in-car speed limiters: Field studies. *Transportation Research Part C, 9,* 191-211.

The study assessed the effects of SL usage for varying speed limits and the acceptability among its users. The SL systems were installed on 290 cars in three countries: the Netherlands, Spain and Sweden. In each vehicle, the SL was placed in an unobtrusive location. Cars with the devices traveled on roads with varying posted speed limits. It was found that the SL was most effective in locations where the posted speed limit was the highest. In addition, it was also noted that, in areas of congestion, the SLs were effective in reducing the speed variability. This was done through suppression of temporary speed increases. Of those that tested the SLs, 50 percent of drivers stated that they would accept an SL mandate.

Organisation for Economic Co-Operation and Development and European Conference of Ministries of Transport. (2006). *Transportation Research Centre: Speed Management.* ISBN 92-821-0377-3. Organisation for Economic Co-Operation and Development (OECD) and European Conference of Ministries of Transport (ECMT).

As part of a larger examination of speed management trends and techniques, recent developments in vehicle engineering which could play an important role in improving safety are cited. They note the work in ISA technology, specifically the two broad ISA categories that are being assessed for possible wider deployment: “Informative ISA” which displays the speed limit and advises the driver when the limit is being exceeded, and “Supportive ISA” which intervenes through the vehicle speed control system to give feedback to the driver when the speed limit is being exceeded.

The authors encourage progressive implementation of ISA, on a cost-effectiveness basis, given the potential benefits. Appropriate actions could include:

- All new cars equipped with manually adjustable SLs (where the driver chooses the maximum speed), and later with informative or supportive ISA, to assist drivers in keeping to both static and, eventually, variable speed limits.
- Mandatory ISA in the long term.
- Governments and other relevant partners start developing the necessary digital speed-limit databases to support implementation of ISA.

1.3.3.2 Safety Technology Usage by Motor Carriers

Cantor, D.E., Corsi, T.M., and Grimm, C.M. (2006). Safety technology adoption patterns in the U.S. motor carrier industry. *Transportation Journal, 45,* 20-45.

Cantor et al., conducted a national survey of large motor carriers operating in the United States (n = 415) to identify safety technology adoption practices. The survey focused on 26 technology types generally classified into driver communication, vehicle communication, and driver performance/assistance technologies. Cantor et al., found that the industry is in the early stages of adopting safety-related technologies. The research also found that larger trucking companies were leading the way in technology adoption. In addition to company size, the authors found that large trucking companies that operate over larger geographic areas were most likely to adopt these technologies. These companies had the organizational resources to support the adoption and use of safety-related technologies. However, the authors also found that commodity had little impact on a carrier’s likelihood to use these technologies.

McDonald, W., and Brewster, R. (2007). Survey of Motor Carriers on Issues Surrounding the Use of Speed Limiting Devices on Large Commercial Vehicles. American Transportation Research Institute, Arlington, VA.

As part of a larger effort to determine the consequences of the industry's increasing use of SLs (and subsequent increase in truck/automobile interactions), a convenience survey (n = 240) of the industry was conducted to identify the ideal speeds for maximizing different operational objectives such as productivity, safety, and fuel economy. Survey respondents represented all major sectors of the industry and carrier sizes. The study found that nearly two-thirds (63 percent) of motor carriers use SLs on at least a portion of their fleet. Use of SLs was more prevalent among larger carriers. In addition, the study found that larger carriers were more likely to adopt lower maximum speeds than were smaller fleets. Carriers that did not use SLs believed SLs actually decreased safety by increasing the interaction between large trucks and automobiles. The average maximum speed for respondents was 111 km/h (69 mi/h). SL settings were most often based on the posted speed limits in the areas of operation (57 percent) and fuel considerations (15 percent).

Owner-Operator Independent Drivers Association. (2007). *Speed Limiter Survey Results Final Report.* Owner-Operator Independent Drivers Association, Grain Valley, MO.

In 2007, OOIDA sent an SL survey to all of its members. Of the 3,422 respondents, each submitted answers to questions about SL preferences as well as advantages and disadvantages to having one installed. More than 60 percent of all those who completed the survey indicated that they drove for companies in which SLs were required. Although many noted that having the SL was part of a trade-off to having a higher wage and benefits, more than 80 percent stated that they would rather drive for a carrier that did not require an SL. According to drivers, this was due to the fact that it reduced the driver's ability to complete a delivery on time, especially when traveling in congested areas. In addition, more than 80 percent admitted that, in areas where the posted speed limit was lower than the SL setting, they traveled at faster rates than was legal.

Transportation Research Board. (2008). CTBSSP Synthesis 16: Safety Impacts of Speed Limiter Device Installations on Commercial Trucks and Buses. Transportation Research Board, Washington, DC.

A comprehensive literature review synthesis was completed to understand and examine research related to SLs within Australia, Europe, and North America. As a component of the synthesis, researchers used the literature findings to develop and distribute an SL survey to the CMV industry. The survey was comprised of 27 questions and distributed to approximately 1,500 recipients with a response rate of 7 percent (103 responses).

Survey results indicated that the majority of respondents (88 percent) believed that CMV drivers tended to increase speed while driving where the posted speed limit was below that of the SL. However, findings also suggested that driver behaviors were more likely attributable to the speeding rather than the SLs themselves. More than half of the respondents (56 percent) said that SLs were either successful or very successful in reducing crashes. Similarly, 64 percent indicated that speeding violations were successfully reduced. A large portion (77 percent) suggested that the SLs had neither a positive nor negative result on driver hiring or retention. Almost all respondents said that SLs have not had a negative effect on productivity (96 percent) or safety (96 percent).

1.3.4 Safety Results from Implementation

The key aim of this section was to establish the level of safety-relevant research results regarding the implementation of SLs. Although analytical progress has been made in recent years, empirical results are still lacking.

National Highway Traffic Safety Administration. (1991). *Commercial Motor Vehicle Speed Control Safety.* Report to Congress, DOT-HS-807-725. National Highway Traffic Safety Administration, Washington, DC.

In a study conducted by NHTSA, the effect of SL use on truck crashes was examined. According to the study, due to higher interstate speed limits of 105 km/h or more (65 mi/h or more), a large percentage of SL trucks would still be driving at the maximum posted speeds. However, most (95 percent) single-unit truck crashes occur on roads where the speed limit is less than 105 km/h (65 mi/h). The authors argue that this creates a lack of authority for the argument that SLs would be needed to reduce speeds and decrease the number of crashes on most roadways.

Different types of SLs were also examined in this report to determine possible benefits. One issue brought to the forefront was speeding while traveling downhill. Since many SLs available to fleets only measure engine speed, it is possible for drivers to travel at speeds far higher than 105 km/h (65 mi/h) downhill. In addition, although SLs are marketed as tamper-resistant, it is possible for drivers to alter the devices. Therefore, the authors concluded that public information and educational programs may be the most effective approaches to obtaining SL compliance.

Repussard, J-P. (2007). Study on speed limiters. Email Correspondence. European Commission Directorate General Energy and Transport, Unit E3-Road Safety.

Mr. Repussard confirmed that there has been no EU-wide study as to the safety impact of SLs. When the legislation was being passed, he states that supporting documents quoted “some studies” pointing to the positive/negative impacts (not further referenced) and also quoted similar comments from some Member States (Denmark, Spain, Luxembourg, and the United Kingdom). He noted that the road accident rate for trucks has been decreasing faster than the general vehicle population but also cautions that it is not possible to quantify the specific contribution of SLs due to the variety of factors.

Transport Canada. (2008b). *Safety Implications of Mandated Truck Speed Limiters on Canadian Highways*. Transport Canada No. TP-14807. Transport Canada, Ottawa, Canada.

The Safety Implications Study aimed to determine whether SLs would reduce the risk and severity of truck crashes. It also assessed the safety impact of speed differentials and car-truck interactions in a SL environment. In the study, traffic simulations for three highway scenarios were conducted in addition to a case study of a Canadian freeway section.

Simulation results showed that truck SLs set at 105 km/h (65 mi/h) increase safety in uncongested traffic flow. This is true for all geometric configurations, especially straight segments. If SLs are set at 110 km/h, the safety gains are reduced in uncongested traffic. The simulations showed that the maximum safety gains were obtained when SLs were set at 90 km/h (56 mi/h) in uncongested traffic.

Specifically for the freeway case study, which was applied to the Eastbound Queen Elizabeth Way (QEW) in Toronto, the study concluded that the introduction of SLs set at 105 km/h yielded statistically significant safety gains as compared to the base case of no mandatory SLs. Over 30 simulation runs the average safety increase was 16 percent, with positive safety gains observed in 21 of the runs.

There are cases in which the crash risk increases when traffic volumes and truck ratios increase. For example, for traffic volume above 1,250 vehicles per hour per lane, SL trucks cause more vehicle interactions to take place, which leads to a reduction in safety due to lack of space to adjust speed or lane. This is especially true for segments with increased merging and lane-change activity, due to on and off ramps. The authors note that this finding is based on simulation of uncongested traffic. In the real world, as traffic volumes approach capacity, the vehicle speeds will be dominated more by congestion, such that the SL limited vehicles will be operating below the speed limit and, therefore, the SLs would not be expected to have an effect on safety. Nevertheless, they do acknowledge that, given the volume of trucks on some Canadian freeways and traffic volume overall, this result could present some “safety challenges” with the introduction of SLs.

The authors noted that, although it is logical that crashes would be reduced following a lowering of the maximum speed limit for all vehicles in the traffic stream, the challenge is to determine the effect of a strategy that targets one group of vehicles (trucks) and not another (cars). The related implications for altering speed differentials in the traffic stream with possible increases in traffic turbulence. Increased turbulence would be expected to increase the number of crashes and crash severity. The authors suggest speed variance, rather than mean speed, explain the likelihood of crashes on freeways. And, speed variance provides a better explanation for “turbulence” in vehicular flow by increasing lane change behavior and acceleration/deceleration profiles and hence increases in traffic conflicts and crashes.

Transport Canada. (2008a). *Final Report: Learning from Others: An International Study on Heavy Truck Speed Limiters.* Transport Canada No. TP-14810. Transport Canada, Ottawa, Canada.

This study was conducted as part of a comprehensive study on SL impacts for trucks operating in Canada. Australia, Sweden, and the United Kingdom were selected for the international assessment. Each participating jurisdiction’s SL legislation, national compliance approach, enforcement methods/regime, measures of effectiveness, and summary views from road transport stakeholders were documented.

Although the status of SL implementation in these countries has been covered in other sections of this literature review, it is instructive to review what the authors of this report considered to be the most salient conclusions from this investigation. They note that the European Commission and Australia implemented SL legislation based on concerns over road safety due to a high incidence of crashes involving heavy trucks and concerns over the environmental impact of fuel emissions due to heavy-vehicle speeding. In both cases, no research or empirical studies were done prior to enacting the legislation to justify the implementation of the SL requirement. Furthermore, the authors note that 10 years later, no empirical studies have been conducted in any participating jurisdictions to directly link the use of SLs with improvements in road safety. Additionally, they cite a lack of research on the safety impacts of truck-car speed differentials due to SL trucks. The study concluded that it is difficult to predict the potential road-safety impacts of an SL mandate in Canada.

Road-safety concerns as a result of the SL requirement have been noted by U.K. and Swedish officials. This problem resulted in U.K. officials restricting heavy trucks to the inside lane of motorways and Swedish officials restricting truck overtaking on some sections of the highway. In the United Kingdom, the inside lane restriction may have addressed the heavy-truck overtaking issue, but government officials acknowledge this may have created other problems in terms of other traffic being able to easily access exits or merge onto motorways.

Transport Canada. (2008c). *Speed Limiter Case Study and Industry Review. Final Report.* Transport Canada No. TP-1002769. Transport Canada, Ottawa, Canada.

This case study, involving two large Canadian carriers, was conducted to document the benefits and experience of SL usage within the Canadian trucking industry. Two large trucking firms were selected through their respective trucking associations, one for-hire carrier and one private carrier. Both were based in Ontario and together have about 400 power units on the road. Both firms have operated with SLs since the mid 1990s. These fleets believed SLs had a significant positive impact on safety, fuel savings, and other maintenance costs.

Both carriers believed that their lower fleet speed has resulted in an improved safety record. About half of their reported crashes were low-speed (on company property), resulting in property damage only. For the remaining crashes, the study noted that there was no evidence of vehicles rear-ending trucks in these fleets. More generally, the crash data analyzed do not show any evidence that SLs are contributing to the occurrence of crashes. Both carriers believe that their speed control policy has resulted in a reduction in crashes, but no empirical data supports this contention.

Drivers from these fleets were interviewed in the study. The drivers did not believe the speed control policies created any significant operational or safety concerns. Further, they generally accepted the speed control policy and expressed satisfaction with their jobs.

Thiffault, P. (2009a). *Safety implications of mandating speed limiters for motor carriers in Canada.* Currently unpublished. Transport Canada, Ottawa, Canada.

This document reviewed the scientific literature to rebut the position that SL implementation can reduce safety due to alleged safety risks of the resulting speed differentials. Regarding absolute speed, the author cites literature to argue that absolute speed increases the difficulty of the driving task, which is particularly true for trucks, as speed exponentially increases an already problematic braking distance and complicates tracking in emergency situations. Absolute speed increases crash risk and exponentially increases crash severity.

Regarding speed differential, the author cites additional literature to argue that, although there is a consensus that faster moving traffic increases risk, the risks associated with slower traffic are far from being conclusive. Although speed differential only contributes to a limited portion of road crashes, absolute speed increases crash risk and crash severity for all types of crashes. The potential impacts of SL implementation on the speed differential are complex. This would increase the differential between trucks and speeding traffic. However, the increase in the differential between mean truck speed and mean traffic speed is likely to be small. He also notes that SLs would reduce speed differentials among trucks, SLs for trucks would decrease the overall mean speed of traffic, and SLs would prevent speed variances resulting from speeding trucks overtaking traffic traveling at the posted speed limit.

The author concludes that the literature on the speed differential and absolute speed issues suggests that: SLs would decrease the crash risk of trucks currently traveling faster than 105 km/h (65 mi/h), as well as the severity of their crashes when they do occur. SLs for trucks would generate some positive effects on the speed differential because this would decrease the variance within the trucking population and prevent trucks from overtaking cars traveling at or around the speed limit. There is no evidence that slightly increasing the mean speed differential by slowing down trucks to 105 km/h (65 mi/h) will increase crash risks for trucks; and the increase in interactions between speeding cars overtaking speed-limited trucks and the associated risks are uncertain, calling for more research in this area. The overall conclusion was that the scientific literature does not provide a justification to reject an SL mandate on the basis of safety risks.

Organisation for Economic Co-Operation and Development and European Conference of Ministries of Transport. (2006). *Transportation Research Centre: Speed Management.* ISBN 92-821-0377-3. Organisation for Economic Co-Operation and Development (OECD) and European Conference of Ministries of Transport (ECMT).

This report noted that SLs can have some potentially negative impacts on safety. It cited results of traffic flow measurements on major truck routes which showed that road capacity (vehicles per hour) could deteriorate over time as the proportion of SL trucks rises (as SLs increase the time required for equipped vehicles to overtake other traffic). Based on the literature, there is concern about the potential for increases in the overtaking of SL trucks on two-lane roads, which could lead to more truck-related crashes.

The report also points out that SLs do nothing to reduce speeding on roads with posted speed limits below the set speed, nor on downgrades steep enough to cause free-rolling. The authors believe that, in some cases, truck drivers may be tempted to always reach the maximum speed set by the SL. Nevertheless, the report concludes that SLs have contributed significantly to reducing accidents involving trucks. Further, there are many countries where SLs are not used and consideration should be given to mandatory SLs for trucks and motorcoaches.

1.3.5 Other Benefits Attributed to Speed Limiters

Examinations of non-safety benefits relating to SLs have focused mainly on fuel economy. Fleet operators clearly have the perception that SLs can increase fuel economy. This section describes other benefits attributed to SLs.

Transportation Research Board. (2008). CTBSSP Synthesis 16: Safety Impacts of Speed Limiter Device Installations on Commercial Trucks and Buses. Transportation Research Board, Washington, DC.

This literature review synthesis was completed to understand and examine research related to SLs within Australia, Europe, and North America. As a component of the synthesis, researchers used the literature findings to develop and distribute an SL survey to the CMV industry. The survey was comprised of 27 questions and was distributed to approximately 1,500 recipients with a response rate of 7 percent (n = 103). The survey found that, in operational terms, SL users consider SLs to be either “successful” or “very successful” in reducing tire wear (44 percent) and increasing fuel economy (76 percent). Regarding driver hiring and retention, 77 percent of respondents see SLs as a neutral factor.

Transport Canada. (2007a). *Final Report: Environmental Benefits of Speed Limiters for Trucks Operating in Canada.* Transport Canada No. TP-14811. Transport Canada, Ottawa, Canada.

This study quantified the potential annual diesel fuel savings and GHG reductions from a national SL mandate in Canada. The study concluded that 228 million liters of fuel could be saved annually, which is 1.4 percent of the total diesel fuel that was consumed by all road vehicles in Canada in 2006. The annual GHG savings are estimated at 0.64 megatons, with Ontario and Quebec combined accounting for 64 percent of the estimated national savings.

Hammerstrom, U., and Yahya, M. (2007). Speed Regulator and Fuel Consumption of Heavy Trucks with Trailer—Result of Reducing Maximum Speed from 89 to 85 kph. Swedish National Road and Transport Research Institute, VTI notat 32-2006.

Given that trucks in Sweden with a GVM of greater than 12 tons have been required to be equipped with an SL since 1992, the authors worked with CMV fleets to investigate the effects of changing speed regulator settings from 89 km/h (55 mi/h) to 85 km/h (53 mi/h). Test results were based on 12 trucks from 5 companies. Due to inconsistent methods, the results were somewhat ambiguous, showing an increase in fuel consumption, with a maximum change of 3 percent. The researchers noted that data were not collected for other factors at play—such as road type and load—which could have affected fuel consumption. The report concluded that lowering the speed setting by 4 km/h (2 mi/h) would result in an estimated reduction in fuel consumption of less than 1 percent.

Transport Canada. (2007b). Final Report: Trade and Competitiveness Assessment of Mandated Speed Limiters for Trucks Operating in Canada. Transport Canada No. TP-14813. Transport Canada, Ottawa, Canada.

This assessment investigated the potential trade and competitiveness impact of mandating SLs under two scenarios: an Ontario/Quebec mandate and a national mandate. The general conclusion is that there would likely be very few competitiveness issues because the majority of large North American fleets already use SLs. The concerns about an SL mandate that do exist come from smaller North American fleet operators and owner-operators, who typically either don't use SLs or have them set at higher speeds. These operators cite safety concerns, indicating they would avoid operating in speed-limited jurisdictions. There were also concerns that SLs would negatively affect driver recruitment and retention; however, fleet managers contended that drivers are more likely to consider pay, monthly mileage, and fringe benefits as the dominant factors here.

The assessment also included a cost analysis to determine the potential trade-off between productivity benefits and increased costs. This analysis concluded that increased fuel costs from operating at speeds higher than 105 km/h (65 mi/h) are greater than any productivity gains. An overall cost savings of 2 percent was found when operating at 105 km/h (65 mi/h) compared to 113 km/h (70 mi/h), and a 9.5 percent cost savings was found when compared to operating at 121 km/h (75 mi/h). The total fuel savings from a national mandate was estimated at 228 million liters annually. Expressed in monetary terms, this could be roughly $200 million annually.

1.3.6 Literature Review Summary

Based on crash data from several studies, speeding was one of the primary factors in motor vehicle crashes and this risky behavior was compared to driving with a BAC of 0.08. Documented disadvantages to speeding included a possible increase in transloading, a higher probability of being involved in a crash, and an increase in the severity of the crash. Several sources used a mathematical analysis to assess the relationship between crashes and speed, and found that higher speeds increase crash-related fatalities.

Speed is clearly a factor in crashes, but the literature is mixed in terms of the relationship of speed to posted speed limit. Some sources note that crashes occurring when the vehicle was traveling above the posted speed limit are minor compared to the case of traveling too fast for conditions; however, other sources note a preponderance of interstate-related crashes in which the vehicle was exceeding the speed limit. Although the literature review did not yield any citations of empirical studies specifically assessing the safety effectiveness of SLs on long-haul trucks, estimates of the potential benefits have been made. SLs have been mandated in Europe for more than 10 years, and U.K. data show that the crash involvement rate for SL trucks fell 26 percent between 1993 (when mandated) and 2005. U.K. authorities noted that other contributing factors may have influenced the decline, but concluded that SLs played a significant role. Other countries, such as Australia, have SL regulations in place and estimate that the posted speed limit reduction may decrease large truck-involved crashes by 29 percent. SLs cannot address speeding on roads with speed limits lower than the SL setting, and the literature shows that speeding continues to be a problem in these situations.

In 2009 SLs were mandated in the Canadian provinces of Ontario and Quebec. In the United States, organizations such as ATA support legislation for SLs, but other organizations, including OOIDA, do not support the use of SLs (citing a possible increase in the interaction between cars and large trucks; thus, higher crash levels). There is still a debate in Congress as to the details of such a law and whether it should be enacted.

The potential for an increased crash risk due to speed variances created by SLs on trucks was addressed in various simulations, showing a significant safety increase for typical conditions. Some sources report that SLs decrease speed variances by minimizing truck-to-truck speed differentials and trucks passing cars. Assertions that earlier literature points to a safety decrease due to SLs must be examined carefully because these studies address either extreme speed variations or highly general cases (which may not apply to the specific conditions created by SL trucks). Furthermore, a strong argument can be made that absolute speed matters more than speed differentials when assessing the total safety picture.

Sources noted many advantages to SLs, such as a reduction in fuel spending, decreasing speed-related crashes and violations, and cohesiveness with already equipped technologies. Traffic effects were noted as a concern in some areas, due to the long distance required for one SL truck to overtake another (and the resulting traffic backlog). This problem resulted in U.K. officials restricting heavy trucks to the inside lane of motorways. The literature reviewed here clearly shows that SL usage is very high in other parts of the world; however, supporting empirical data are minimal. Many fleets support use of SLs because of operational efficiencies as well as some evidence of safety benefits.

1.4 EVALUATION OF SPEED LIMITER IMPLEMENTATION IN COMMERCIAL TRUCKING

This section of the report addresses technologies and techniques in past SL applications, and provides information on current SL devices and manufacturers. Key areas of investigation included the scope and extent of SL applications and costs of implementation. The information contained within this section is the result of interviews with fleet operators, manufacturers, and industry organizations, and a review of relevant literature. Specifically, to bring a range of perspective to the discussion, Representatives across a variety of industries and functions were. For general background information, those interviews included an industry trade council, a truck OEM, and an engine OEM. For questions related more specifically to fleet operations, both private and for-hire fleets across a range of fleet sizes and industry segments, including truckload (TL), less-than-truckload (LTL), and specialized fleets were contacted. Due to the sensitive nature of these conversations, all responses have been made anonymous and incorporated into the summary below. For motorcoaches, information and perspectives were received from the motorcoach industry via contacts with the American Bus Association and the United Motorcoach Association.

1.4.1 Speed Limiter Technology: Status and Availability in Heavy Trucks

Current SL technology is mature technologically. SLs are standard equipment on new trucks and have been for some time, with the core technology built into the ECM. No evidence was found of SL availability in the aftermarket. Historically, SLs existed as distinct, mechanical parts. These parts generally did not function very well, and were fairly easy to bypass. Over time, the trucking industry moved toward electronic engine management systems for a number of reasons, including durability and lower maintenance costs. Newer trucks are built to be vertically integrated, with significant interaction between all the system components.

An important part of this new, vertically integrated system was the ECM. Although SLs are still represented as separate and distinct parts, maximum speed is simply a setting on the ECM contained within every engine. There are a number of ECMs located throughout the vehicle, each governing different systems (e.g., brakes, engine, etc.). The ECM that governs the engine has a number of parameters that can be set, including maximum speed. As the overall system became more complicated in recent years, the ECM followed, with more and more settings and parameters. Again, these changes were driven by system needs as a whole, and maximum speed was simply one of the first settings that came along. Some of these settings can be altered by a fleet using a simple PC service tool connected to a standard data bus (e.g., maximum speed, etc.), and some settings are designed to be set by the manufacturer and not modified by the owner (e.g., those relating to Environmental Protection Agency [EPA] standards).

Therefore, since at least 1994, every large truck engine comes with the ability to limit speed. In some cases, the engine may arrive from the OEM preset, or the setting may be left for the fleet to determine. Although the ECMs themselves may differ in settings available and calculation methods (e.g., idle time reporting) across different engine OEMs and truck manufacturers, the maximum speed setting is straightforward and nearly identical across these different segments.

1.4.1.1 Engine Manufacturer Findings

The ECM is a computing platform running various software applications; the SL is one feature within this software. The software generally contains a number of different speed control and speed limit features designed to maintain a stable engine or vehicle speed. These features include power takeoff (used to drive auxiliary devices, like pumps, augers, or generators at a fixed speed) and cruise control (used to maintain a constant vehicle speed). Engines typically have one minimum SL for low idle. Engine manufacturers often allow end users to adjust the low-idle set point within a prescribed range. Generally lower speeds conserve fuel, and higher speeds reduce vibrations. The adjustable range allows flexibility to avoid vibrations while minimizing fuel consumption.

Engines have several maximum SLs, including: high idle governor, road speed governor, and a number of other proprietary options, depending on the manufacturer. The high-idle governor limits the maximum engine speed. This limiter sets the maximum engine speed boundary for the engine. The boundary is set by the engine manufacturer for a specific engine rating and cannot be changed or adjusted. This boundary may be set to limit maximum power or to avoid over-revving engine components. The road speed governor limits the maximum vehicle speed. Typically, the limiting value is stipulated by the end user and is trimmed by the truck OEM or end user. End users can use this feature to comply with legislated maximum vehicle speeds.

Various other proprietary SL applications exist, although the industry's use of these applications can change as carriers seek to modify their employees' driving behaviors to fully realize the operational benefits of modern day equipment. Efforts to document these changes are challenged by the diversity of the industry, the industry's response to external factors (e.g., high fuel prices), and the many options available to carriers to modify various SL and engine settings.

The speed-related features that can be trimmed by the end user are generally defined in the vehicle sales specification, which means an end user can order the features trimmed by the OEM. Engine OEMs also offer software packages that allow fleets to trim these settings at will. In many cases the end user may decide to alter trim settings after gaining experience with the features. ECMs are generally prepared for engine OEMs by a supplier and are fairly specialized. Thus, engine OEMs will receive the ECM as one sealed part/component. Then, OEMs mount the ECM on the outside of the engine skin, due to heat concerns. In fact, some engine OEMs will even put a coil of tubing running diesel fuel in contact with the ECM to serve as a cooling mechanism. Note that the software accompanying the ECM is generally proprietary, and the features described above are built within the software. In some cases, engine manufacturers will label the software with a part number, complete with subassemblies. The software is also fairly modular in design, enabling engine OEMs to mix and match abilities as needed.

1.4.1.2 EMA and TMA Comments to Transport Canada

Based on a request for information regarding SL use and technology, comments from the TMA and the EMA (prior to association merger) were published by Transport Canada (2007). TMA represents the following companies: Ford Motor Company, Freightliner Trucks, General Motors Corporation, International Truck and Engine Corporation, Isuzu Commercial Truck of America, Inc., Kenworth Truck Company, Mack Trucks, Inc., Peterbilt Motors Company, Sterling Truck Company, Volvo Trucks North America, and Western Star Trucks. EMA represents all manufacturers of heavy-truck engines, including: Caterpillar Inc., Cummins, Inc., Daimler Trucks North America LLC, MTU Detroit Diesel, Inc., Navistar, Inc., and PACCAR Inc.

SLs are available options on nearly all trucks equipped with electronically controlled engines, and enable fleet operators to optimize their fuel economy or other business factors. Further, nearly all model year 1995 and newer diesel engine-equipped trucks (with GVM rating greater than 11,000 kg) manufactured in North America are equipped with ECMs that have the capability to be programmed to limit the vehicle's road speed. One caveat is that some model year vehicles as new as 2003 were built with mechanically controlled engines that do not include an electronic vehicle SL system. TMA states that they are not aware of any manufacturers that make an electronic road SL for a mechanically controlled diesel engine today.

TMA describes the SL implementation as follows: a transmission output shaft rotational speed input signal is transmitted to the engine ECM. In order to make use of those data, other variables must be defined in the ECM, including transmission output shaft pulses per revolution, tire rolling radius, and rear axle gear ratio. EMA notes that the engine ECM is calibrated by the vehicle manufacturer, dealer, and/or owner to reflect the choices of tire size, rear axle ratio, and transmission top gear ratio for the road speed limit function to operate correctly. Heavy duty vehicle speedometers also use this calibration of the vehicle speed signal to display vehicle speed to the driver. EMA emphasizes that the accuracy of the SL setting is dependent upon the accurate capture of these variables (which are unknown at the time of engine manufacture).

There are several industry standards incorporated into engine ECMs that relate to the vehicle speed sensor signal, data, and diagnostics provided by SL systems. TMC RP 123 defines a convention for speed signals. Signals from transmission drive shafts are standardized at 16 pulses per revolution, but many engines do not require that the signal contain exactly 16 pulses and these can use other conventions. Multiplexed signals from an electronically controlled transmission (transmission output shaft speed) and the antilock brake system (wheel speed) are also used to provide the raw speed signal to the engine, typically using the SAE J1939-71 standard.

Vehicles can coast faster than their vehicle speed limit setting on downhill grades. Several manufacturers have recognized the importance of maintaining momentum in rolling terrain and provide a way to achieve a modest increase in speed over the set limit on a downhill slope to provide additional momentum for the next uphill slope. This concept mimics the engine speed overrun performance that was typical of mechanically governed engines, and provides smooth transitions between fueled and non-fueled engine operation at highway speeds.

A number of manufacturers offer software that allows the driver to temporarily override the SL. In some cases, the vehicle owner sets the allowable over-speed, and other approaches allow a maximum variation around the specific speed setting. There also may be a driver reward feature available where the vehicle owner allows a higher speed limit for drivers with good fuel economy habits. Another option allows the cruise control limit to be set higher than the specific SL value to encourage the use of cruise control. A few manufacturers offer the option for driver adjustment from inside the cab.

Although many owners possess the software that allow them to change the SL settings as desired, other operators do not have this ability and must rely on the dealer to access the settings if changes are desired. Generally, this service is not performed without an associated charge. The cost of the software and hardware to enable changes by the owner is estimated to be between $500 and $1,000. Fleets that purchase large quantities of engines and vehicles often get the benefit of the software and hardware as part of their purchase. This is usually not the case with purchases of single vehicles and engines.

The speed setting cannot be adjusted without the proper OEM-supplied equipment (interface, software, etc.). The speed limit setting is secured with a password unique to the vehicle that is given to the owner of the vehicle. The owner of the vehicle can then change the password as desired. The vehicle owner controlling and limiting access to the password is a key principle in preventing improper changes. The industry associations contend there has been no need to take extraordinary steps to make the SL setting tamper-resistant. These associations state that tampering with the vehicle speed limit setting or one of the associated parameters is not believed to be commonplace.

1.4.2 Speed Limiter Technology: Status and Availability in Motorcoaches

Prior to the advent of electronic controls, SLs in the form of mechanical flyweight governors were standard for motorcoaches. Originally, the primary function of the SL was to prevent engines from exceeding their maximum RPM rating, as well as in limiting the vehicle's maximum speed. However, since the mechanical SL was very easy to tamper with, engine manufacturers decided to make the erasable programmable read-only memory (EPROM) on the electronically controlled engines adjustable only by the manufacturer. This eliminated tampering, so that the vehicle's top speed was limited and the manufacturer was better able to contain warranty costs.

Electronically controlled engines have been in use since the mid-1980s. As such, the vast majority of the commercial motorcoach fleet is equipped with these. In terms of equipment, the current situation with motorcoaches is much the same as with large trucks (since they use the identical engines and control technology). Speed limiting is a function of the factory-programmed EPROMs and operators have the option to designate the factory set speeds and do so for safety, fuel economy, and engine/powertrain life. After delivery, operators optionally have the ability to adjust the maximum speed via a password-protected protocol.

1.4.3 Speed Limiter Usage: Scope/Operational Techniques in Heavy Vehicles

1.4.3.1 Speed Limiter Use

OOIDA research indicates that the overwhelming majority of small carriers (20 trucks or less) do not employ SLs and this represents 96 percent of the U.S. trucking industry (OOIDA, undated). Note that this is the fraction of carriers and not trucks. Most trucks are operated by large carriers, with approximately 50 percent of the trucks operated by 0.5 percent of the carriers (Motor Carrier Management Information System Census file). In a survey conducted by the OOIDA Foundation (2007), questionnaires were sent to the company driver portion of their membership (approximately 15,000 drivers). Survey responses from 3,422 drivers represented 2,080 trucking companies. The results indicated that 60.8 percent of trucking companies use SLs.

A survey (McDonald and Brewster, 2007) found that overall installation rates of SLs were 63 percent for motor carriers, which are comparable to rates identified in the OOIDA study for company drivers.

In a convenience survey of carriers conducted by TRB (2008), 79 percent of respondents reported using SLs compared to 64 percent of the TL sector, 54 percent from the LTL sector, and 58 percent from the specialized sector. Overall, 63 percent of carriers reported using SLs. These carriers that used SLs accounted for 77 percent of the trucks, a testament to the increased likelihood among larger carriers to use SLs. Eighty-two percent of respondents used SLs in at least some of their vehicles (averaging 90 percent). Of the 82 percent of respondents who indicated using SLs, 95 percent used factory-installed SLs and have done so for an average of 11.5 years.

In summary, OOIDA contends that owner-operators typically do not employ SLs. For company-owned trucks, the surveys conducted by OOIDA and ATRI, and the TRB study indicate that 60 to 63 percent use SLs, with variations across sectors. The investigation for this report yielded higher estimates for fleets.

1.4.3.2 Motivation and Cost

In the TRB (2008) study, almost 56 percent of respondents indicated SLs were either "successful" or "very successful" in reducing crashes. In operational terms, SL users believed that SLs were either "successful" or "very successful" in reducing tire wear (44 percent) and in increasing fuel economy (76 percent). Almost 96 percent of respondents indicated SLs did not negatively affect safety or productivity. In the investigation for the current report, every fleet interviewed indicated some combination of fuel conservation and safety as the primary motivation in activating SLs. Additionally, one fleet identified significant benefits in terms of decreased maintenance needs and decreased tire wear. Every fleet interviewed agreed that the cost to implement SLs was negligible. In fact, it appears that external costs only accrue to fleets which require dealers or maintenance centers to adjust the SL settings. In this situation, the fleet is required to pay for the needed labor. Often, larger fleets perform this work in-house.

1.4.3.3 Speed Setting and Operational Approach

According to comments submitted to Transport Canada by EMA and TMA, significant numbers of carriers choose to set the SL at or below 113 km/h (70 mi/h). They referenced a survey which indicates that more than 50 percent of Class 7 and 8 trucks sold have this SL setting. However, this may not be especially meaningful, given that the operator can change the setting after delivery of the vehicle. The OOIDA Foundation Survey (2007) found that 6.3 percent of SLs were set at 97 to 100 km/h (60 to 62 mi/h), 50.6 percent were set at 101 to 105 km/h (63 to 65 mi/h), and 43.1 percent were set at 106 to 109 km/h (66 to 68 mi/h). Here it should be noted that the response categories in the survey were limited to a maximum of 109 km/h (68 mi/h) as the survey was specifically addressing the Canadian SL regulations under consideration at that time. Therefore the survey provides no indication as to the number of companies that have SLs set above 68 mi/h.

Generally, larger fleets appeared to have more standardized policies regarding the use of SLs. For instance, one large fleet set the maximum speed limit at 105 km/h (65 mi/h) for the entire fleet. Regardless of size, if a fleet used a policy concerning SLs, then every truck in the fleet was required to have the maximum speed setting enabled. Of the fleets interviewed in the current report, none indicated having programs in place that allowed qualifying drivers to operate vehicles at higher speeds. Additionally, none of the fleets interviewed used aftermarket parts in their efforts to limit speed.

Although driver tampering may have been a problem with mechanical systems, the problem seems to have been largely alleviated by new software-based systems. Every fleet interviewed used a password to secure the maximum speed setting. In one case, a fleet recounted how a driver had guessed the password and paid an engine maintenance center to reconfigure the maximum speed setting. However, such reconfiguration leaves an “electronic trail” which exposed the offending engine maintenance center, and the offending driver was reprimanded.

In the TRB (2008) study, survey results indicated that SL settings on the SLs were within a fairly narrow range of about 6 km/h (4 mi/h) (e.g., 105 to 111 km/h or 65 mi/h to 69 mi/h). Most respondents (90 percent) selected safety as the primary consideration for determining the set speed on their speed limiters, followed by fuel mileage (69 percent) and posted speed limit (56 percent). Respondents were evenly split in terms of setting a different cruise control speed limit from the on-pedal (non-cruise control) speed limit. The majority (56 percent) of respondents did not use this practice. The difference in set speed between cruise-control and on-pedal (non-cruise control) SL was not noteworthy. The mean setting for the cruise-control speed limit was 106 km/h (65.6 mi/h) and 108 km/h (67.2 mi/h) for on-pedal operations (a difference of only 2.6 km/h or 1.6 mi/h).

About 12 percent of respondents in the TRB (2008) study operated with variations in the top speed of the SL based on driver performance. For drivers considered inexperienced or risky, speed settings were reduced. For example, one company used a policy in which all students were set at 105 km/h (65 mi/h); veterans were set at 113 km/h (70 mi/h); and if a driver was put on probation for any safety-related reason, he/she was set at 105 km/h (65 mi/h).

1.4.4 Speed Limiter Usage: Scope and Operational Techniques in Motorcoaches

Most commercial motorcoach fleets operate with SLs set at 116 km/h (72 mi/h); however, many companies have settings below 113 km/h (70 mi/h). Use of SLs is motivated primarily by safety, as well as savings in fuel cost and maintenance. Since the SL capability is a standard feature on all engines used in the industry, there is no cost increase to the operators above the initial vehicle price.

1.4.5 Future Trends

Since limiting speed happens through electronic systems, there are some interesting future possibilities that could apply to both heavy trucks and motorcoaches. By integrating ECMs with telematics systems, SLs could actually be adjusted “on the fly.” For instance, when a truck crosses a State line that moves the speed limit from 105 km/h (65 mi/h) to 113 km/h (70 mi/h), the ECM could communicate with a back-office system run by the State and automatically adjust the maximum speed to the appropriate State level. In addition, digital maps which have detailed speed limit data could be employed to adjust SL settings appropriately as speed limits change. Such technology may be offered in the future. The comments from EMA and TMA as published by Transport Canada (2007) noted that dynamic adjustment of a vehicle speed limit has been discussed by industry associations. Their comment was that no standardized method of operation has been defined for all vehicles to use, whether based on geo-fencing or satellite communications, such that the ability to adjust remotely did not exist at that time.

There is some momentum on the passenger car side that could eventually have some bearing on heavy-vehicle SLs. Vision-based systems currently available on luxury cars in Europe have the capability to detect and read speed limit signs, displaying this information to the driver. This system was first introduced in Europe due to the greater consistency in speed limit signage. Conceivably, this type of information could provide the current speed limit to a dynamic SL system, once techniques are developed for robust speed detection in North America. Before vehicle speed can be automatically set by data derived from camera and digital map data, it is essential that map-updating techniques and robust video-based image processing algorithms be implemented to ensure that the vehicle is truly following the correct speed limit. This would include being responsive to dynamic speed limits.

1.4.6 Summary of the Evaluation of Speed Limiter Implementation in Commercial Trucking

SLs are standard equipment on new trucks and motorcoaches and have been for some time (with the core technology built into the ECM). Historical problems related to driver tampering have been alleviated by the current electronic systems. Because the SL capability is standard, the cost to implement SLs is negligible, although some external costs do accrue to fleets in cases where external maintenance centers are used to change SL settings.

Fuel conservation and safety were named as the most important benefits of SLs in trucks and motorcoaches. Providing drivers with an incentive for improving performance, or rewarding past performance, are other benefits offered to carriers through the use of SLs. In terms of the use of SLs across the industry, there are a variety of opinions. For trucking, OOIDA contends that owner-operators typically do not employ SLs. For company-owned trucks, the surveys conducted by OOIDA (2007), ATRI, and the TRB (2008) study indicated that 60 to 63 percent use SLs (with variations across sectors). The investigation in the current report yielded much higher estimates for fleets, in the range of 75 to 80 percent. Most motorcoaches operate with SLs.

With regard to SL settings, the OOIDA (2007) survey found that the preponderance of drivers operate in the range of 101–109 km/h (63–68 mi/h), but it is possible that this survey did not account for vehicles set above 109 km/h (68 mi/h). EMA and TMA contend that carriers set speeds at or below 113 km/h (70 mi/h). The TRB (2008) study found SL settings to fall within the 105–111 km/h (65–69 mi/h) range. In the current investigation, SL settings ranged from 100–113 km/h (62–70 mi/h). Most commercial motorcoach fleets operated with SLs set at 116 km/h (72 mi/h); however, many companies have settings below 113 km/h (70 mi/h).

As to variations in speed settings depending on driver skill or the use of cruise control, the TRB (2008) study found that approximately half of the respondents used this practice, with only minor differences for cruise control use. However, the investigation in the current study found that none of the fleets used programs to allow qualifying drivers to drive at higher speeds. Technology trends indicate that vehicles will eventually be “speed limit aware” based on data derived from a camera and/or digital map data. However, it is essential that map updating techniques and robust video-based image processing algorithms be implemented to ensure that the vehicle is truly following the correct speed limit, including dynamic speed limits.

2. METHODS

As stated above, this project aimed to identify SL effects in reducing the severity and frequency of crashes, best practices in SL applications, and identification of carrier, insurer, and enforcement official views related to SL implementation. To accomplish this goal the following tasks were performed: a peer review to obtain feedback on the proposed research design and analyses, CMV stakeholders were interviewed, vehicle and crash data were collected directly from motor carriers, crash data were reduced to standardize crash types across carriers, and the crash data were analyzed to identify the extent to which SLs reduced the frequency of crashes.

2.1 PEER REVIEW PROCESS

A peer review meeting was conducted to obtain feedback on the proposed methodology to assess the safety benefits of SLs in CMV operations. Due to the fact that the industry-wide use of speed governing devices on commercial trucks and buses involves a diverse group of stakeholders, the participants on the panel were selected to include representation from each stakeholder category. Below lists the many groups that would be affected by the implementation of SL devices and/or who could provide important information related to their potential effectiveness, costs, and benefits. The objective of this portion of the effort was not for the participants to indicate their support or disapproval of SLs; rather, it was to specifically address the efficiency and effectiveness of the data collection and analysis methodology to be used in this study.

- Truck and bus companies.
- Truck and bus industry organizations.
- Driver organizations.
- Highway safety advocacy organizations.
- Truck and bus manufacturers.
- Academic researcher organizations.
- Engine manufacturers.
- Federal and State agencies.

2.1.1 Selection of Review Panel Participants

Because the study addressed the safety and operational cost aspects of the implementation of SLs, stakeholders from both of these areas are included in the Peer Review Panel. Two forums that included these stakeholders were attended by the peer review members: the ATA Technology and Maintenance Council Fall Meeting and the ATA Safety Management Council Conference. These discussions subsequently helped finalize the list of potential stakeholders that were asked to participate on the Peer Review Panel. After approval of the list by FMCSA, the potential panel members were contacted by telephone and asked if they were willing to participate and available for the Peer Review Panel meeting. A total of 27 participants were included in the Peer Review Panel.

2.1.2 Webinar for Offsite Participants

Prior to the meeting date, the offsite participants were given the Web site address with instructions on signing in, along with a password. Figure 5 shows the screen used by the offsite participants to interact with the panel. The slides of the Research Analysis Plan presentation were shown on the screen and the presentation could be downloaded and printed by the participants. The *Draft Research Analysis Plan* could also be downloaded from the site, although it had already been sent to all of the participants.

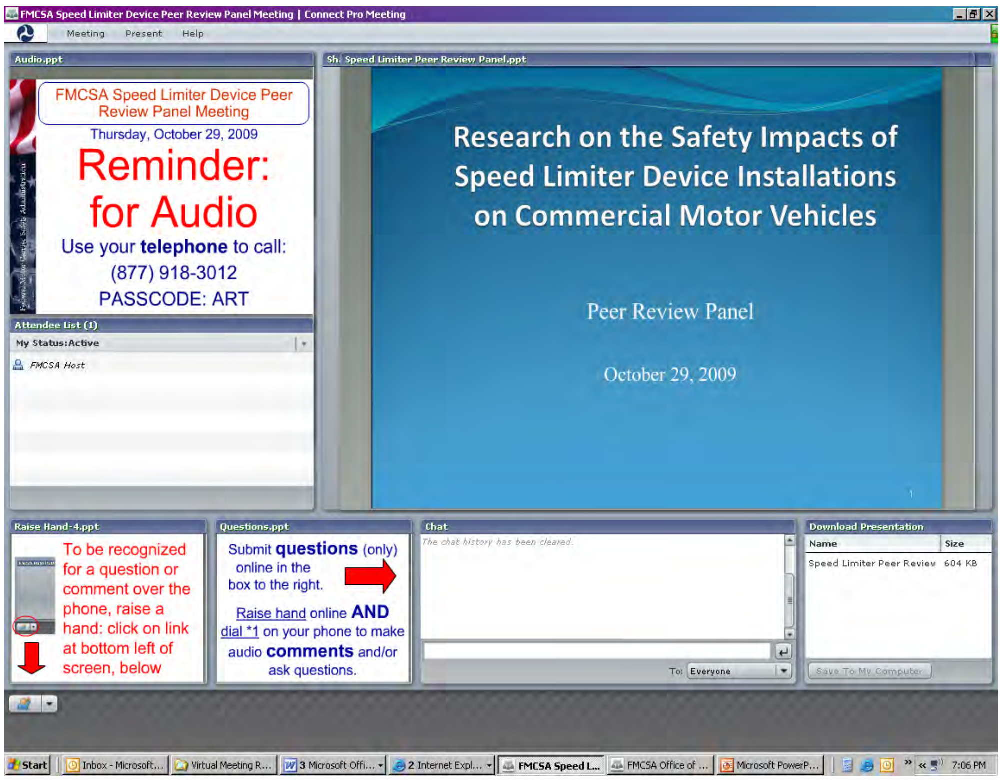

Figure 5. Screen Shot. Webinar Conference Screen Used by Offsite Participants.

The offsite participants could either type their comments/questions or call them in. If the questions/comments were typed into the Web page, both the research team and the other participants could read them and respond. The 3-hour peer review meeting was very interactive, with extensive discussions among the participants during the presentation of the Research Plan. At the completion of the presentation, the primary areas related to the data collection and analysis methodology that had surfaced were discussed in a more structured format. The primary areas of discussion during the peer review meeting are summarized below.

- The operational definition of “speed limiter-relevant crashes.”
- Alternative data sources.
- Measures of exposure.
- Time period to include in the study.
- Representatives of the fleets used for the study.

- Driver characteristics.
- Other safety factors.
- Operational costs.
- Sample size (number of fleets and trucks).

2.1.3 Peer Review Panel Web Site to Obtain Additional Comments and Recommendations

Although the formal meeting was very beneficial as a way to present and discuss the Preliminary Research Plan, the 3-hour time limit inherently constrained the potential contributions by the 27 members of the panel. A Web site was developed to allow the Peer Review Panel participants to provide additional comments and recommendations after they had a chance to reflect on the discussions during the meeting. The Web site allowed the participants to both interactively comment on the research design and comment on the issues brought up by the other panel members. The content and structure of the Web site was established from the notes taken during the Peer Review Panel meeting as well as from the transcript of the meeting. The outline of the Web site content that was used to focus the participants' comments is given below.

- **Research Design.**
  - Before-and-after comparison of fleets that have recently installed or will install speed-limiting devices during the study period.
  - Comparison of fleets that set limiters and those that do not.
  - Comparison within fleets that have trucks that use limiters and trucks that do not.
  - Comparison of fleets that use different SL settings (e.g., 62 mi/h versus 70 mi/h).
  - Comparison within fleets that have reduced their SL settings.
  - Other alternative or complementary approaches.
- **Use of Fleet Safety Data.**
  - Fleet safety data content and quality.
  - Measures of exposure.
  - Time period for data used in the study.
- **Choice of Fleets.**
  - Types of operations.
  - Commodity hauled.
  - Method of driver compensation.
- **Choice of Roadways.**
- **Alternative Sources of Data.**
- **Operational Cost Analyses.**
  - Fuel costs.

- Maintenance costs.
- Other operational costs.

- **Statistical Analysis.**
  - Analysis of safety data.
  - Analysis of operational costs data.

- **Other Factors that Impact Accident Rates and Severity.**
  - Weight of truck.
  - Enforcement of speed limit laws.
  - Traveling downhill.
  - Driver distraction.
  - Hours of Service.

In addition to the areas of discussion derived from the Peer Review Panel meeting, the Web site also included a list of the names of the research team and the peer review panel membership.

Another function of the Web site was to allow the Peer Review Panel to comment on the report from Phase I (summarized above). The panel members could download the report and make comments on the Web page. The Web site outline for the report was as follows.

Literature Review

- Executive Summary.
- Safety Impacts of Speed.
- Speed Limiter Regulation.
- Speed Limiter Technologies and Usage.
- Safety Results from Implementation.
- Other Benefits of Speed Limiters.
- Key Findings.
- References.

2.1.3.1 Logistics of the Web site

The Peer Review Panel participants were emailed their individual User Name and Password to access the Web site (http://Truckingsafetyresearch.com). Figure 6 shows the home page of the Web site.

Figure 6. Screen Shot. Home Page for Peer Review Panel Web Site.

The panel members could direct their comments by selecting (clicking) the heading at the top of the page or the outline to the right. Figure 7 shows an example of a page on which the participants input their comments and recommendations.

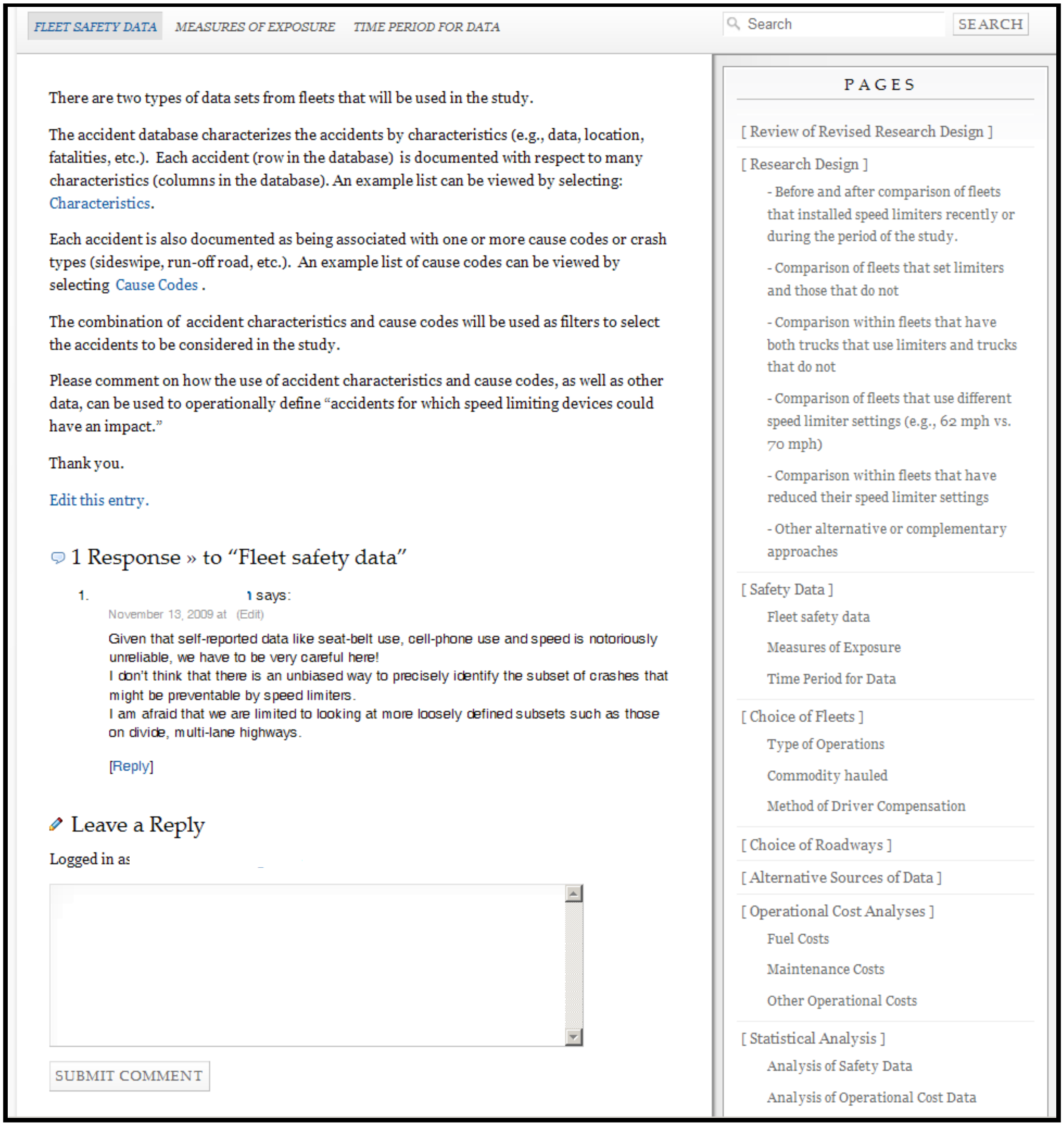

Figure 7. Screen Shot. Example of the Interactive Web Site Comments and Reply Area.

The narrative for each Web site page (e.g., *Fleet Safety Data*) was developed from the combination of the *Preliminary Research Plan* and the discussion during the Peer Review Panel meeting. The panel participants had two weeks to provide comments and recommendations to the Web site. The research team reviewed the comments from the Peer Review Panel Web site on November 24, 2009. The comments were addressed with respect to the technical and financial feasibility, as well as consistency with the scope of the project. Subsequently, a *Revised Research Analysis Plan* was developed.

FMCSA recommended that the *Revised Research Analysis Plan* be sent to the panel members that represent the academic research community for review and comment. The comments by this group indicated that they agreed with the statistical analysis approach of using a logistic regression modeling approach. The primary concerns for this group remained the same as those previously indicated by the panel as a whole. In particular, there was a concern about the sample size (fleets and trucks, within fleet) that is necessary to have sufficient power to detect the impact of SL devices. The other comments by the academic group reflected the same concerns as the larger group (i.e., that the control or adjustment for the confounding factors is critical to the validity of the study).

2.2 DATA ANALYSIS METHODS

As previously discussed, a number of motor carrier research studies have shown that the use of SLs in CMV operations may improve safety (by reducing crash risk and/or crash severity). FMCSA has determined that it is important to go beyond these studies and the recently completed literature review by Bishop et al. (2008) to provide a better understanding of SL implementation effects, both from safety (reduction in crash numbers and severity) and economic (increased fuel economy) points of view. The data in the current study were collected directly from truck fleets and represent a wide array of truck crash types: from minor incidents (e.g., scraping an object with a mirror) to fatal crashes. The following research questions were assessed in the current study:

- Is there a significant difference in the overall crash rate between the SL and non-SL cohorts?
- Is there a significant difference in the SL-relevant crash rate between the SL and non-SL cohorts?
- Will different settings on the SL (e.g., 67 mi/h versus 70 mi/h) have a significant impact on safety?

2.2.1 Research Design

The study design determined the overall structure of the research and guided data collection and analyses. The main objective of the current study design was to quantitatively evaluate the safety impact and associated fuel benefits of SLs in CMVs. Study designs could be divided into two general categories: the experimental study and the observational study (depending on how treatment/exposure was determined). The current study was an observational study because of the lack of control over the activation and/or installation of an SL in a truck; this decision was made at the fleet level. As such, the study followed an epidemiological approach (Rothman, Greenland, and Lash, 2008).

Two study designs, the before-after and the retrospective cohort approaches, were considered. In general, the retrospective cohort approach is less prone to time trend bias (e.g., safety regulations, etc.), but is subject to the potential confounding effects caused by individual truck variations (e.g., safety culture, safety technologies, etc.). The before-after approach has the advantage of smaller bias caused by individual truck/fleet variation, but is subject to the confounding effects of time trend. The before-after approach is noted here because it was indicated as the preferred approach in the statement of work; however, this approach was not feasible after reviewing preliminary carrier data (i.e., the study team could not identify fleets that had enough data to perform this analysis approach). Given the small frequency of "speed limiter-relevant" crashes (i.e., crashes in which an SL may have prevented the crash and/or reduced crash severity) and the inability to control for time (as each carrier activated its speed limiters at different times), the retrospective cohort design was selected as the optimal approach.

2.2.1.1 Retrospective Cohort Approach

The main objective in the current study was to determine the safety benefits of SLs (i.e., do trucks with an active SL have a lower crash risk than those without an active SL?). Since preliminary data obtained by the research team showed that SL crashes were rare events, there were two levels of exposure status in this design: trucks with an active SL (yes), or trucks without an active SL (no). More specifically, SLs were considered to improve safety if the trucks with an active SL had a lower crash risk than trucks without an active SL.

Two classical epidemiological methods were considered in the current study: case-control and cohort methods. The primary difference between these two methods is the direction of study. In the cohort study, the SL status of each truck is determined first (i.e., trucks with an active SL and trucks without an active SL). Subsequently, the safety outcomes of each truck are determined. In the case-control method, crashes involving a truck with an active SL are identified first. Subsequently, a group of trucks without crashes is selected as a control and the status (yes/no) of their SL activation is determined.

The cohort study has several advantages over the case-control study. The cohort study is less prone to bias compared to the case-control approach and is considered the gold standard in observational studies (such as the current study). Bias is caused by improper control selection; however, this approach can be cost-effective for rare safety events (such as crashes). As it was possible to collect the SL status in all trucks in the current study, the cohort study is preferred (Rothman, Greenland, and Lash, 2008).

Figure 8 illustrates a schematic plot of the retrospective cohort method used in the current study. The study followed a retrospective cohort design approach, based on whether an SL was equipped/activated. The trucks were divided into two groups: an SL cohort and a non-SL cohort. Note that the two cohorts may not reflect SL carriers versus non-SL carriers, but rather trucks with an active SL versus trucks without an active SL within the participating carriers. However, the data collected in the current study reflected fleet-wide use or non-use of an SL (i.e., all the trucks in a specific carrier had an active SL or vice versa). In each cohort the safety outcome and fuel consumption in a specific study period were collected from historical records obtained from participating carriers. The safety and fuel benefits of the SL were assessed by comparing the outcomes in the two cohorts.

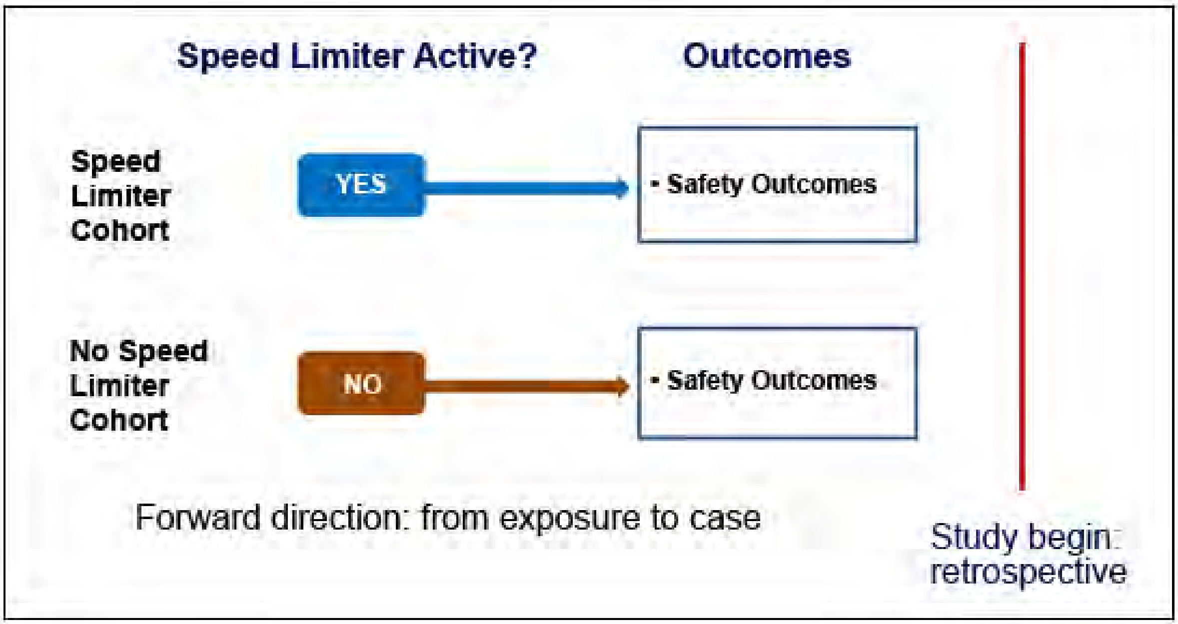

Figure 8. Diagram. Schematic of the Retrospective Cohort Design to be Used in the Current Study.

2.2.2 Data Collection Procedures

The two primary analyses noted above were assessed using carrier-collected data. ATRI was responsible for collecting all data from the participating carriers. ATRI and the research team worked collaboratively in collecting the appropriate data. Once data were collected from the participating carriers, the data were merged (if necessary), column headings were formatted (to uniform headings), a data directory (to identify coding) was created, and a check was made to ensure that all the necessary data elements were included (see below for the necessary data elements). All trucks in the study were Class 7 or 8 trucks.

After these data were collected and formatted, ATRI sent these data, via email, to the research team. Once received by the research team, the database was reviewed to ensure proper formatting. Any issues or discrepancies were resolved through a collaborative process between ATRI and the research team. After the research team validated the database sent by ATRI, trained personnel reviewed each crash file to determine if the truck crash was an SL-relevant crash.

2.2.2.1 Data Elements

Certain data elements were necessary to ensure all analyses were performed correctly. Participating carriers that did not collect the necessary data elements were not included in any analyses. Below is a list of requested data elements to assess the two primary analyses (i.e., safety and fuel benefits). Note that mileage and fuel information were not available from participating carriers. This limited the analyses related to the potential fuel benefits of SLs and confounded the safety analysis on SLs (as there was no ability to control for exposure).

- Crash Information:
  - Date.
  - State.
  - Location (e.g., mile marker on I-81).
  - Contributing factor (e.g., excessive speed).
  - Crash type (e.g., rollover).
  - Crash narrative.
  - Injury (yes/no).
  - Fatality (yes/no).
- Vehicle Information:
  - Vehicle ID number.
  - Vehicle year (e.g., 2008).
  - Mileage (for the study period).
  - Fuel.
- Carrier Information:
  - SafeStat score.
  - Fuel efficiency bonus.
  - Fleet type (e.g., for hire: long haul).
  - SL setting (date and SL, if changed).
  - Driver pay.

2.2.2.2 Data Reduction

Although the current study was similar to analyses assessing the effectiveness of onboard safety systems (OBSS), studies assessing the safety benefits of OBSSs target specific crash types that could have been prevented and/or mitigated with the systems (see Dang, 2004; Houser et al., 2009; Jermakian, 2010; Murray, Shackelford, and Houser 2009a, b). However, a truck with an active SL has many different crash types, and trucks equipped with an active SL will generally not have a crash when the truck is traveling above the preset speed (as the truck is prohibited from traveling above the preset speed unless the truck is traveling down a grade). Thus, the aim of the current study was to identify the types of crashes where an active SL would be most effective in mitigating and/or preventing truck crashes; i.e., high-speed (posted speed limit 97 km/h or 60 mi/h or greater) truck crashes on highways. No trucks in the SL cohort had a setting of less than 97 km/h (60 mi/h).

Trained research personnel who were blind to the SL status of each carrier reviewed several data elements included in the crash file to determine if the crash was an SL-relevant crash. An SL-relevant crash was primarily determined by assessing four different variables in the crash file. Note that this was necessary as the carrier dataset did not include information on the truck's speed at the time of the crash.

Note that the following variables were identified during an initial peer review and various research team meetings.

The first variable was the location of the truck crash. The crash must have occurred on a highway with a posted speed limit of 97 km/h (60 mi/h) or greater (excluding entrance/exit ramps, truck stops, etc.). While several carriers listed the posted speed limit at the time of the crash, others carriers did not. In these instances, research personnel used the location information in the crash file and cross-referenced that information with the Geographic Information System (GIS) to obtain the posted speed limit. Highways with posted speeds limits of 97 km/h (60 mi/h) or greater were selected as these are the roads where SLs are most likely to have a potential safety benefit. Moreover, highway locations such as truck stops and entrance/exit ramps were excluded because it is unlikely an SL would have a benefit in these locations (the truck was likely going well below the posted speed limit).

The second variable was the crash type. Certain crash types were considered indicative of an SL-relevant crash (e.g., rear-end truck striking), while other crash types were clearly not indicative of an SL-relevant crash (e.g., truck was turning right). The specific crash types associated and not associated with potential SL-relevant crashes are shown below.

- **Crash Types Associated With an SL-Relevant Crash.**
  - V1 Into rear of V2.
  - V1 Wrong side of road.
  - V2 Wrong side of road.
  - V1 Passing V2.
  - V2 Passing V1.
  - V1 Changed lanes.
  - V2 Changed lanes.
  - V1 Into stationary object.
  - V1 Ran off road.
  - V1 Hit pedestrian.
  - V1 Overturn.
  - V1 Jackknife.

- V2 Hit object in roadway.
- V1 Out of control.
- V2 Stopped in roadway.
- V2 Hit by V1.
- V1 Hit V2.
- Sideswipe—Merge.
- Sideswipe—Opposite.
- Misc. Unavoidable.
- Misc. Avoidable.

- **Crash Types Not Associated With an SL-Relevant Crash.**
  - V1 Hit by unknown vehicle.
  - V1 Left turn squeeze on V2.
  - V2 Left turn squeeze on V1.
  - V1 Right turn squeeze on V2.
  - V2 Right turn squeeze on V2.
  - V1 Lost wheel.
  - V1 Ran stop sign or yield sign.
  - V2 Ran stop sign or yield sign.
  - V1 Left turn.
  - V2 Left turn.
  - V1 Right turn.
  - V2 Right turn.
  - V1 U-Turn.
  - V2 U-Turn.
  - V1 Pulling away from curb.
  - V2 Pulling away from curb.
  - V1 Into parked V2.
  - V2 Into parked V1.
  - V1 Backing.
  - V1 Rollaway.
  - V1 Loading or unloading.
  - V2 Backing.
  - V1 Pulling away from dock.
  - V2 Pulling away from dock.

- V2 Rollaway.
- V1 Wreckered, not DOT rec.
- Unreported accident.
- Hooking/unhooking.
- Disputed sign or signal.
- Open intersection.
- Dropped TRL or TRK-TRL collision.
- V2 Into rear of V1.
- V1 Hit viaduct/underpass.
- V1 Hit animal.
- V1 Hit object in roadway.
- V2 Out of control.
- Load Shift.
- Hit by unknown object.
- Hit by moving object.
- R/R Crossing.

The third variable was the contributing factor or factors in the crash. The contributing factor variable was used to exclude crashes where speed was clearly not a factor, such as weather-related (e.g., ice, rain, etc.), mechanical-related (e.g., brake failure, tire blowout, etc.), and driver non-performance errors (e.g., asleep, intoxicated, etc.). Note that animal strikes and objects in the roadway were excluded as SL-relevant crashes because most carriers train their drivers to avert an avoidance maneuver in these circumstances (the avoidance maneuver would be more dangerous than striking the animal and/or object).

The fourth variable reviewed by research personnel was the crash narrative. This was the most important variable to review as the other three variables might suggest an SL-relevant crash; however, the crash narrative revealed information that could potentially refute this information. For example, a rear-end truck striking crash on a highway with a posted speed limit of 97 km/h (60 mi/h) or greater with a contributing factor of following too close might appear to be an SL-relevant crash; however, the crash narrative indicated the crash occurred in bumper-to-bumper traffic. See below for a list of keywords that were used to exclude crashes as SL-relevant crashes. These keywords were identified during the review of crashes. Crashes were not sorted by these keywords to exclude crashes, and a SL-relevant crash could contain one or more of these keywords.

- **Keywords Used to Exclude SL-Relevant Crashes.**
  - Left-hand turn.
  - Right-hand turn.
  - Overpass.

– Backing.
– U-turn.
– Mechanical failure.
– Hit by other vehicle.
– Equipment loading damage.
– Traffic device.
– Driveway.
– Curb.
– Residential area.
– Fuel Island.
– Rest area.
– Hooking.
– Bridge w/restrictions.
– Street.
– Mail box.
– Tire blow-out.
– Stop and go traffic.
– Fuel spilling.
– Tire flew off other vehicle.
– Intersection.
– Stop sign.
– Entrance/Exit ramp.
– Heavy traffic.
– Construction zone.
– Damage to landscape.
– Dropped trailer.
– Dock area.
– Turning.
– Deer/animal.
– Fell asleep.
– Rock or other object thrown at truck.
– Trailer door open.
– Pulling-in.
– Flying debris.

- Mirrors knocked off.
- Stopped in traffic.
- Freight shift.
- Medical condition.
- Driving slow.
- Hit by lightning.

Note that all variables were reviewed by data analysts in order to determine if the crash was a SL-relevant crash. Inconsistencies between variables (contributing factor was noted as “asleep” but the crash narrative noted otherwise) were resolved by considering the crash narrative as the most accurate. All crash files were reviewed by two different research personnel. Any discrepancies between these two research personnel were resolved by a third researcher (inter-rater reliability was 97.8 percent and intra-rater reliability was 98.4 percent). Once research personnel completed their review of each crash, the database was merged into a SAS file for analysis.

[This page intentionally left blank.]

3. RESULTS

As indicated, the research team completed seven analyses using the datasets provided by ATRI and formatted and reduced by the research team. These analyses included: carrier demographics and safety management techniques, overall crash rate, SL-relevant crash rate, relationship between SL setting and SL-relevant crash rate, and the relationship between fuel consumption and SL status and setting.

3.1 CARRIER DEMOGRAPHICS

The study collected data from 22 carriers in calendar years 2007, 2008, and 2009. Data from two fleets were removed because of poor data quality (i.e., unable to determine the location of the crash).

Table 9 displays the demographics for the participating carriers, including: presence of an OBSS, Safety Status Measurement System (SafeStat) Safety Evaluation Areas (SEA; driver, vehicle, and safety management), sector, mean trip length, commodity types hauled, number of drivers, compensation for drivers, and the presence of an active SL. As shown in Table 9, there were six carriers without an active SL (non-SL cohort) and fourteen carriers with an active SL (SL cohort).

Table 9. Carrier Demographic and Safety Management Techniques

ID	OBSS	Driver Safety Evaluation Area	Vehicle Safety Evaluation Area	Safety Management Safety Evaluation Area	Sector	Trip Length	Drivers	Commodity Types	Active SL
1	N/A	18.39	30.62	ISD	For-Hire LTL	100–499	>5,000	general freight	Yes
2	100%	N/A	N/A		For-Hire LTL	500+	100–500	general freight, heavy machinery, intermodal	Yes
3	No	34.05	34.06	ISD	For-Hire TL	500+	100–500	beverages, building materials, chem: liquid bulk, general freight, U.S. mail	No
4	Freightliner 79% International 34%	34.05	34.06	ISD	For-Hire TL	100–499	>5,000	beverages, building materials, chem: liquid bulk, general freight, U.S. mail	Yes
5	No	12.61	26.75	ISD	For-Hire LTL	<100	1,001–5,000	general freight	Yes
9	No	N/A	N/A	N/A	For-Hire LTL	500+	501–1,000	general freight	Yes
10	No	17.03	45.41	78.4	For-Hire LTL	100-499	>5,000	general freight	Yes
11	No	13.25	28.43	ISD	For-Hire LTL	100–499	1,001–5,000	general freight	Yes
12	No	12.61	27.39	90.9	For-Hire LTL	100–499	1,001–5,000	general freight	Yes
13	No	31.31	26.88	ISD	For-Hire LTL	500+	501–1,000	general freight, heavy machinery, logging, metal	Yes
14	No	22.34	52.78	ISD	For-Hire LTL	500+	>5,000	general freight	Yes
17	No	37.25	33.87	ISD	For-Hire LTL	500+	501–1,000	general freight, intermodal	Yes
18	No	14.49	24.86	ISD	For-Hire LTL	100–499	1,001–5,000	general freight	Yes
19	Volvo 100%	40.95	24.2	ISD	For-Hire TL	500+	100–500	farm, general freight, refrigerated	Yes
20	85%	67.39	10.43	ISD	For-Hire LTL	100–499	<100	refuse, waste	Yes

ID	OBSS	Driver Safety Evaluation Area	Vehicle Safety Evaluation Area	Safety Management Safety Evaluation Area	Sector	Trip Length	Drivers	Commodity Types	Active SL
21	N/A	48.79	40.78	ISD	For-Hire TL; For-Hire LTL; Owner-Operator; Independent Contractor	500+	>5,000	building materials, chem: dry bulk, chem: liquid bulk, fresh produce, general freight, heavy machinery, intermodal, logging, metal, refrigerated, U.S. mail	No
22	N/A	49.49	45.29	ISD	For-Hire TL; For-Hire LTL; Owner-Operator; Independent Contractor	500+	1,001–5,000	beverages, building materials, chem: dry bulk, general freight, heavy machinery, intermodal, logging, metal, refrigerated	No
23	N/A	64.43	62.63	ISD	For-Hire TL; For-Hire LTL; Owner-Operator; Independent Contractor	500+	1,001–5,000	building materials, chem: liquid bulk, general freight, heavy machinery, metal	No
24	N/A	73.46	52.9	ISD	For-Hire TL; For-Hire LTL; Owner-Operator; Independent Contractor	500+	100–500	general freight	No
25	N/A	23.5	17.64	ISD	For-Hire TL; For-Hire LTL; Owner-Operator; Independent Contractor	500+	100–500	beverages, building materials, chem: dry bulk, fresh produce, general freight, heavy machinery, metal, refrigerated	No

3.1.1 Carrier Demographic and Safety Management Results

The size of the participating carriers varied from fewer than 100 power units to more than 5,000 power units. Exact power unit frequencies were not reported to protect the carriers' anonymity. Also, due to existing non-disclosure agreements, the data were scrubbed of any identifying carrier information (including USDOT number). As shown in Table 9 above, other demographic and safety management characteristics were collected from each carrier. Below is a summary of these carrier-specific characteristics.

- All carriers used a "pay per mile" driver compensation method (including line-haul LTL operations).
- Only a limited number of carriers reported trucks equipped with some type of OBSS. Carriers only reported the presence (yes/no) of an OBSS on a truck and did not report the specific OBSS. The total number of power units with an OBSS was fewer than 1,000 power units in any given calendar year. See appendix B for the number of trucks in each carrier that had an OBSS.
- All participating carriers reported being one of three types of trucking operations: for-hire LTL, for-hire TL, and a mixture of for-hire TL/ LTL owner-operator/independent contractor. As shown in Table 10, five out of six carriers in the non-SL cohort were listed as mixture type, whereas the majority of carriers in the SL cohort (11 out of 14) were for-hire LTL.
- The SafeStat SEA scores evaluate the relative safety status of individual motor carriers with respect to the rest of the motor carrier population. Higher SEA scores reflect poorer performance. Driver SEA scores reflect out-of-service violations, roadside inspections, and moving violations, Vehicle SEA scores reflect violations from onsite compliance reviews, and Safety Management SEA scores reflect closed enforcement cases and compliance reviews. As shown in Table 9 above, all the Safety Management SEA scores were recorded as insufficient data (ISD) and two carriers (2 and 9) did not provide any SEA scores. The mean SafeStat SEA scores by cohort are shown in Table 11. As can be seen in Table 11, the SL cohort had lower Driver and Vehicle SEA scores compared to the non-SL cohort. An "analysis of variance" (ANOVA) indicated that the mean Driver SEA scores in the SL cohort (26.8) were significantly lower than the non-SL cohort (48.96; $F_{(1,16)} = 6.73$, $p = 0.0196$). However, the difference in the mean Vehicle SEA scores between the SL cohort (30.5) and the non-SL cohort (42.2) was not significant ($F_{(1,16)} = 3.57$, $p = 0.077$). Carriers did not provide information on specific safety management techniques. Note that ANOVA provides a statistical test of whether or not the means of several groups are all equal, and therefore generalizes the *t*-test to more than two groups. ANOVAs are helpful as multiple two-sample *t*-tests would result in an increased chance of committing a type I error. For this reason, ANOVAs are useful in comparing three or more means (Hayes, 1994).
- The distribution of mean trip length by cohort is shown in Table 12.

Table 10. Frequency of Sector by SL Status

Sector	SL Cohort	Non-SL Cohort
For Hire Less-Than-Truckload	11	0
For-Hire Truckload	3	1
For-Hire TL; For Hire LTL; Owner-Operator; Independent Contractor	0	5

Table 11. SafeStat SEA Scores by SL Status

SEA Score	SL Cohort	Non-SL Cohort
Mean Vehicle Safety Score	30.5	42.2
Mean Driver Safety Score	26.8	48.9

Table 12. Frequency of Mean Trip Length by SL Status

Mean Trip Length (miles)	SL Cohort	Non-SL Cohort
<100	1	0
100–499	7	0
≥500	6	6

3.2 DESCRIPTIVE CRASH DATA

The data from the 20 carriers were collected in calendar years 2007, 2008, and 2009. Some carriers did not provide crash records for all 3 years; thus, the dataset was unbalanced. Due to the lack of mileage information and the unbalanced years collected by fleet, the research team used number of trucks per year (truck-year) as an exposure measure. Table 13 shows the truck-years involved in one or more crashes as well as the number of crash-free truck-years over the data collection period.

Table 13. Number of Crashes and Crash-Free Truck-Years by SL Status

Crash Status	SL Cohort	Non-SL Cohort	Total
Truck-Years With Single Crash	13,091	2,076	15,167
Truck-Years With Multiple Crashes	520	2	522
Trucks-Year Without a Crash	111,781	10,605	122,386
Total Truck-Years	125,392	12,683	138,075

3.2.1 Preliminary Crash Rate

The frequency of trucks involved in crashes, crash-free trucks, and crash rate by cohort is listed in Table 14. Both overall crash rate and SL-relevant crash rate (see operational definition above) were evaluated. As shown in Table 14, the data include 15,866 crash records. Approximately 15 percent of the crashes were identified as SL-relevant crashes (2,372 out of 15,866). The safety impact of SLs was evaluated by the crash rate, which was defined as the ratio of crash frequency divided by the number of truck-years multiplied by 100 (as shown in Table 14). Thus, the unit of the crash rate was the frequency of crashes per 100 trucks/year (e.g., a crash rate of 10 would indicate that 10 crashes would occur for every 100 trucks each year).

The overall crash rate for trucks without an SL was higher compared to trucks equipped with an SL (16.4 versus 11.0 crashes per 100 truck-years). To further evaluate the safety effects of an SL, the SL-relevant crash rate was calculated. Similar to the overall crash rate, carriers without an SL had a much higher rate than carriers with an SL (5.0 versus 1.4 per 100 trucks-years).

Table 14. Crash Frequency and Crash Rate by SL Status

Frequency	SL Cohort	Non-SL Cohort	Total
SL-Relevant Crashes	1,736	636	2,372
Total Number of Crashes	13,786	2,080	15,866
Total Number of Truck-Years	125,392	12,683	138,075
SL-Relevant Crash Rate*	1.4	5.0	–
Overall Crash Rate*	11.0	16.4	–

*The unit for crash rate is the number of crashes per 100 trucks/year.

3.2.1.1 Crash Rate by Carrier and Year

As noted, crash data from participating carriers were collected in calendar years 2007, 2008, and 2009. Because many of the carriers provided data for multiple calendar years, it was more informative to evaluate the overall and SL-relevant crash rates by carrier and year. The frequency of overall crashes, SL-relevant crashes, and the number of crash-free trucks are shown in appendix C. Figure 9 and Figure 10 display the overall crash rate and SL-relevant crash rate across each carrier in the non-SL cohort and SL cohort. Carriers that reported multiple years of data are listed multiple times in the x-axis (e.g., carrier 3 is listed three times as it submitted 3 calendar years of data). The overall and SL-relevant crash rates varied drastically among carriers. More specifically, carriers 5, 18, and 21 had much higher overall crash rates than the other carriers. A review of the crash records by data analysts indicated that the criteria for inclusion as a crash record were quite different among carriers. Some carriers only included major crashes (e.g., significant property or vehicle damage), and other carriers included all types of crashes, including minor crashes (e.g., truck drove over bush, truck scraped mirror against a building, etc.). However, the SL-relevant crashes identified by the research team had a consistent operational definition across fleets.

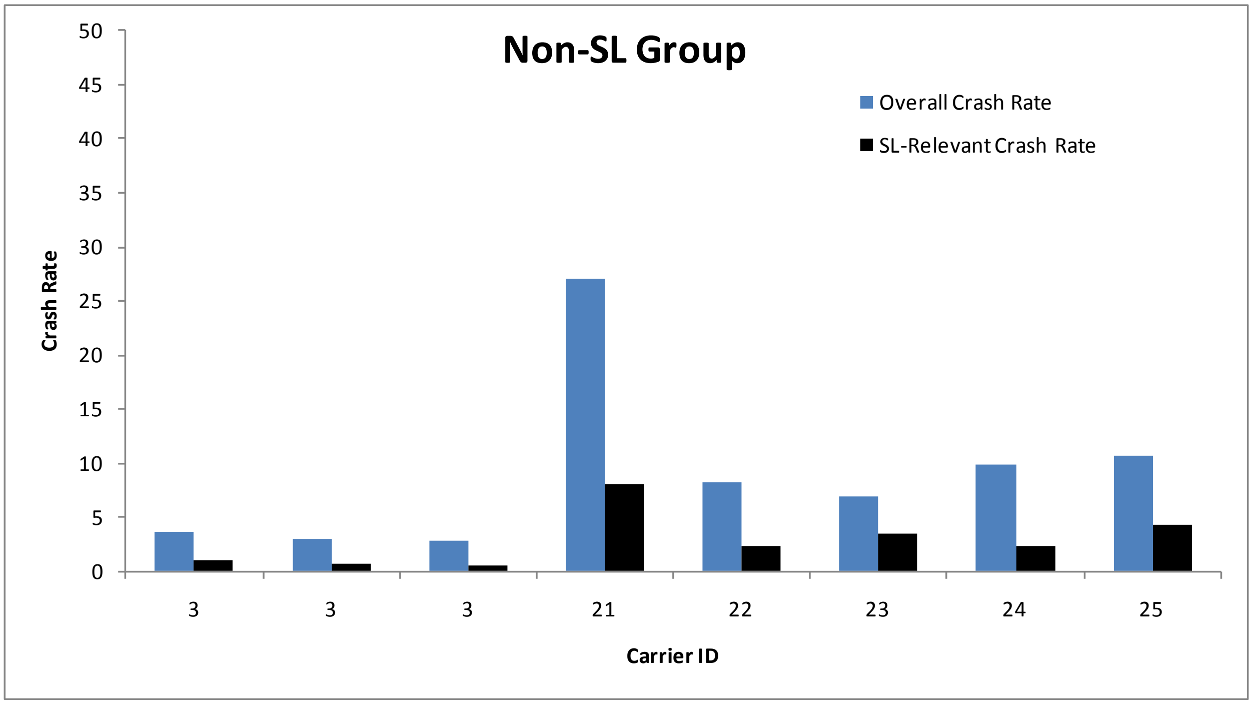

Figure 9. Graph. Overall Crash Rate and SL-Relevant Crash Rate by Carrier in the Non-SL Cohort.

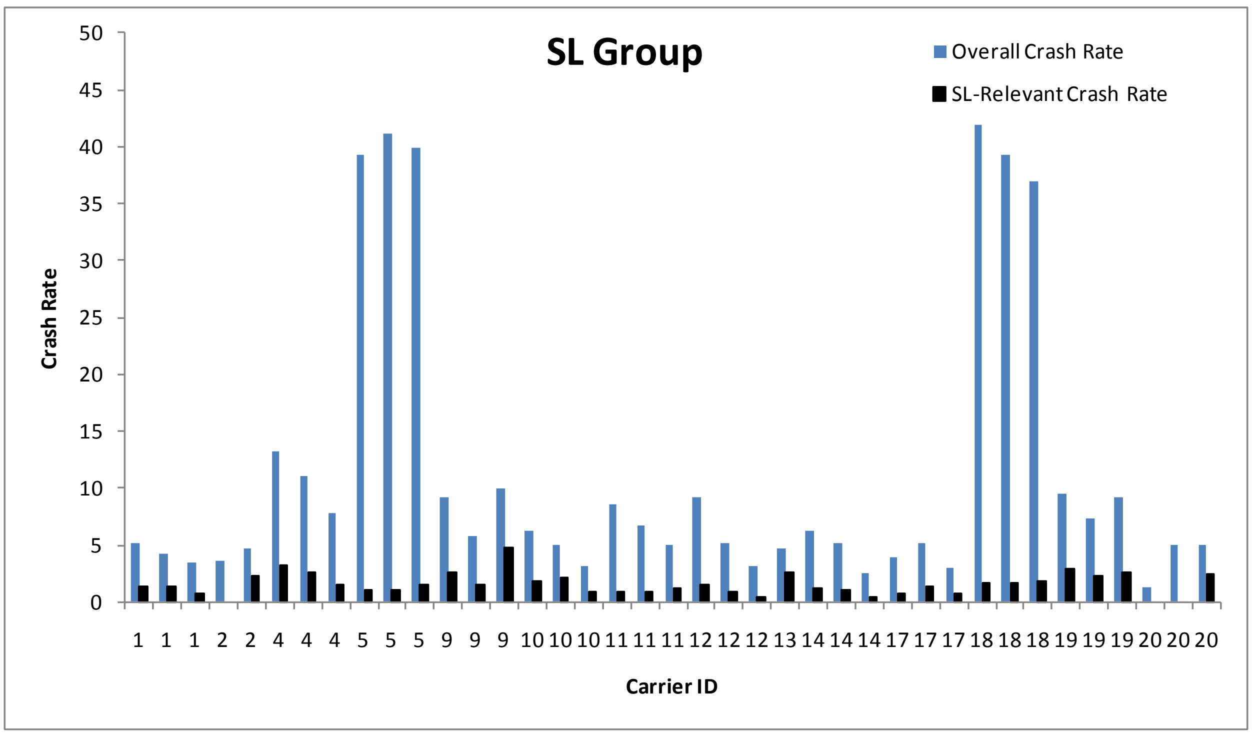

Figure 10. Graph. Overall Crash Rate and SL-Relevant Crash Rate by Carrier in the SL Cohort.

The mean overall crash rate and SL-relevant crash rate across carriers and years in the SL cohort (dark red) and non-SL cohort (light red) are shown in Figure 11. It is interesting that the overall crash rate and SL-relevant crash rate show a different pattern. However, there was no significant difference in the overall crash rate when comparing the non-SL cohort (9.1 per 100 trucks/year) and SL cohort (11.2 per 100 trucks/year; $F_{(1,45)} = 0.22$, $p = 0.645$). An ANOVA found that the SL-relevant crash rate was significantly higher in the non-SL cohort (2.9 per 100 trucks/year) compared to the SL cohort (1.6 per 100 trucks/year; $F_{(1,45)} = 6.5$, $p = 0.014$). Note that the mean crash rate is the average of crash rates by fleet and year. The raw crash rate was aggregated over all fleets; thus it places more weight on large fleets. The research team considered the average of fleet-year level crash to be a more robust estimation. In summary, the SL cohort had a statistically significant lower SL-relevant crash rate than the non-SL cohort, and the overall crash rate between the SL cohort and the non-SL cohort did not differ significantly.

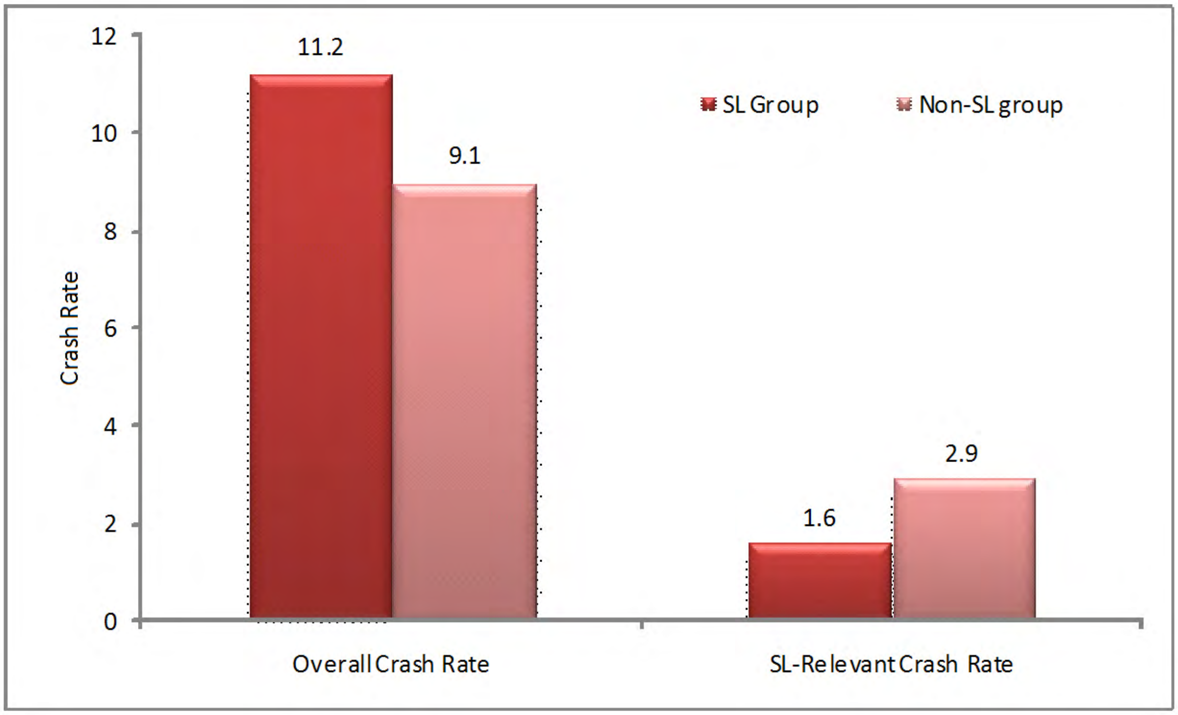

Figure 11. Chart. Average Overall Crash Rate and SL-Related Crash Rate in the SL and Non-SL Cohorts.

To further quantitatively evaluate the safety effects of SLs, the research team used a negative binomial regression model to model the crash count, which is the state-of-practice in modeling accident frequency (Lord and Mannering, 2010). It is particularly suitable for overdispersion data where the Poisson regression model, another commonly used approach, cannot fit the data well. The model in Figure 12 is comprised of the following: let Y_{ij} be the number of crashes for carrier i in year j. Note that Y_{ij} is assumed to follow a negative binomial distribution, where μ *(mu)* $_{ij}$ is the expected number of crashes for carrier i in year j, and k is an overdispersion parameter.

$$Y_{ij} \sim \text{Negative Binomial}\ (\mu_{ij}, k)$$

Figure 12. Equation. Negative Binomial Regression Model.

The mean μ *(mu)* is assumed to be affected by the number of trucks in the carrier and the presence of an active SL. The model in Figure 13 is comprised of the following:

$$\log(\mu_{ij}) = \log(E_{ij}) + X_{ij}\beta + a_i$$

Figure 13. Equation. Log(μ_{ij}) in the Negative Binomial Regression Model.

where E_{ij} is the number of trucks in carrier *i* in year *j* and X_{ij} is the vector of covariate and *beta* is the regression coefficient, *alpha* $_i$ is a random effect associated with carrier *i*. This model incorporated the effects that some carriers contributed multiple calendar years of data. The impacts of an active SL can be evaluated by the significance of β *(beta)*. The exponential of *beta* is the ratio of crash rate between Non-SL cohort and SL cohort.

The model outputs are shown in Table 15 and Table 16. Table 15 provides the estimates for variance in the carrier-specific random effect and overdispersion parameter and Table 16 provides the estimates for the effects of an active SL. The overdispersion parameter is much smaller than one, which indicates the presence of overdispersion and is in support of the negative binomial model. Consistent with the simple ANOVA above, the presence of an SL showed a significant association with the SL-relevant crash rate ($p = 0.0295$). The estimated SL-relevant crash rate ratio was 1.94 (95 percent Confidence Interval: 1.07–3.49), which indicates that the SL-relevant crash rate for carriers in the non-SL cohort was twice that for the carriers in the SL cohort. Put another way, the rate for SL-relevant crashes was approximately half of the rate for trucks with a SL as compared to trucks without an SL.

Table 15. The Mixed Effect Model Covariance Parameters Estimates

Covariance Parameter	Subject	Estimate	Standard Error
Intercept	Carrier	0.2288	0.1060
Overdispersion Parameter		0.09642	0.03742

Table 16. The Effects of SL Status on the SL-Relevant Crash Rate

Label	Regression Coefficient Estimate	Standard Error	*P* Value	SL-Relevant Crash Rate Ratio	95% Confidence Interval
Non-SL Versus SL	0.6610	0.2875	0.0295	1.94	1.07–3.49

Confounding effects could potentially be addressed by including the other factors in the model. However, the data collected are highly unbalanced, which make this approach not feasible. For example the sector variable, the SEA score, and the trip length variable (Table 10 to Table 12) are all highly correlated with the SL status. Including these variables could lead to identification issues and none of the variables was significant. Therefore, the research team adopted the model with only the SL status.

3.2.1.2 Relationship Between SL Setting and SL-Relevant Crash Rate

Figure 14 shows a plot of the relationship between the SL setting (in mi/h) in each carrier and the SL-relevant crash rate. The x-axis displays the SL setting and the y-axis displays the SL-relevant crash rate. Note that some carriers changed their SL setting in a calendar year; so these carriers were listed more than once, thus accounting for the extra plotting points. There was no meaningful relationship between the SL setting and the SL-relevant crash rate (r = 0.053, p = 0.75).

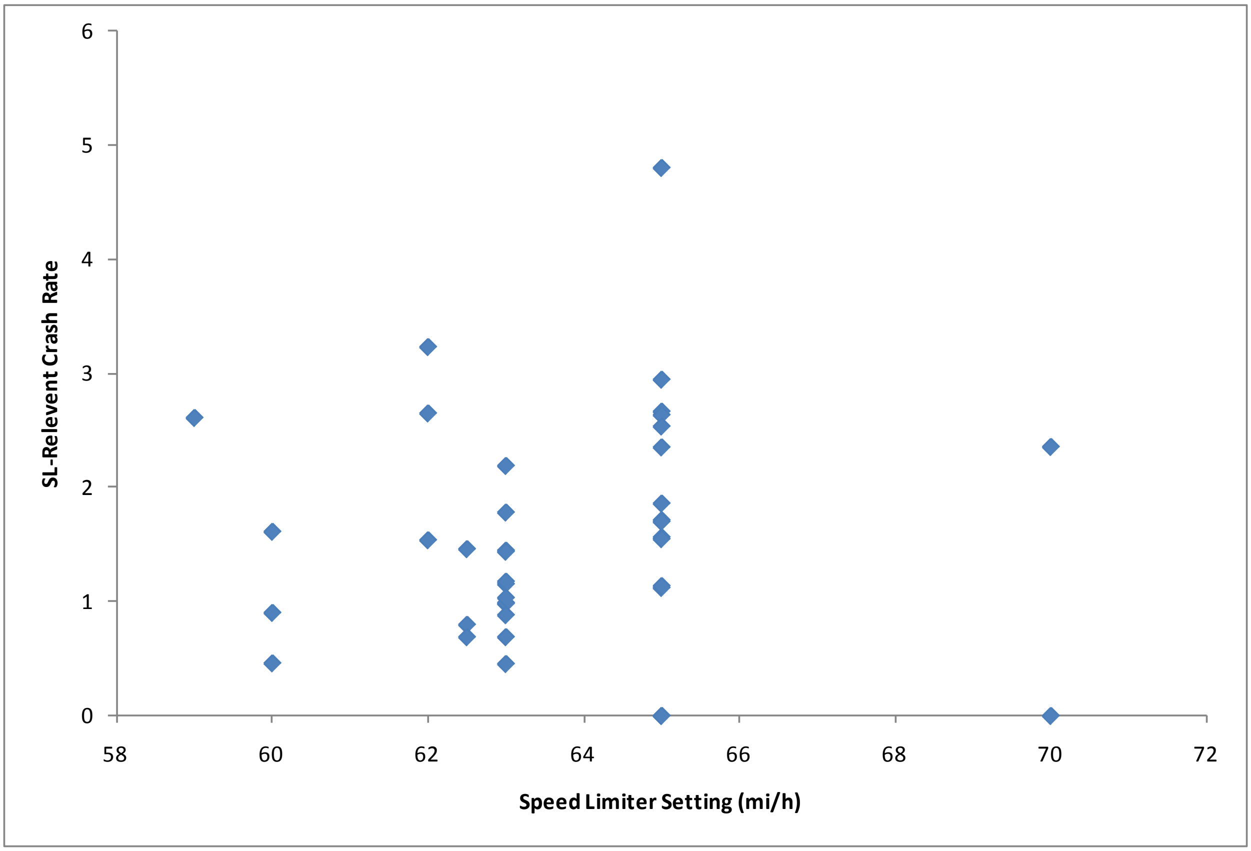

Figure 14. Graph. Plot of SL Setting and SL-Relevant Crash Rate for Carriers in the SL Cohort.

4. DISCUSSION

4.1 CONCLUSIONS FROM ANALYSES OF EFFECTIVENESS OF SPEED LIMITERS IN COMMERCIAL MOTOR VEHICLES

The current study assessed the safety benefits of SLs as they operate during normal revenue-producing deliveries. Whereas other studies have assessed the safety benefits of SLs in cars (Comte, 1996; Van Loon and Duynstee, 2001; Makinen and Varhelyi, 2001), used simulations (Liu and Tate, 2004; Toledo, Albert, and Hakkert, 2007; Transport Canada, 2008b), and assessed crash rates in differential posted speed limits (Baum et al., 1991; Harkey and Mera, 1994; Johnson and Pawar, 2005), the current study used real-world data collected from carriers. Crash data from 20 carriers representing small, medium, and large carriers hauling a variety of commodities were used. The data from these carriers included 15,689 crash records and 122,386 crash-free trucks. In addition, data were collected over a 3-year period (2007–09).The approach used in this research went far beyond any previous study in this domain.

4.1.1 Safety Benefits of Speed Limiters

The primary safety analysis conducted in this study focused on the potential reduction in truck crashes that could have been avoided and/or mitigated by installing an active SL. The data used in the study was divided into two groups: trucks with an SL and trucks without an SL. The crash data were grouped into two groups as well: crashes that were SL-relevant and crashes that were not SL-relevant. Analyses included ANOVAs and data modeling (random effect negative binomial distribution). The results across analyses indicated a strong, positive safety benefit for SLs.

The ANOVA resulted in two key findings. First, there was no statistically significant difference in involvement in the overall crash rate as a function of truck type (SL vs. no-SL, $p = 0.65$). However, for SL-relevant crashes, there was a strong statistically significant difference in crash rates showing a clear benefit for trucks with a SL ($p = 0.01$). This is an important combination of findings and serves as a control of unmeasured variables that could possibly have contributed to the benefits observed for the SL cohort. As noted in the U.K. study (Transport Canada, 2008a), it is possible that contributing factors other than the presence of a SL might have influenced observed benefits. For example, it could be (and this was not measured or controlled for) that fleets with SL trucks also had in place a positive safety culture. If so, one could make the argument the positive effects observed might not have been due to the SL technology, but rather due to other safety protocols (i.e., safety culture). However, if this was the case, one would expect to see safety benefits in the overall crash rate as well in the SL-relevant crash rate. Why would safety culture, for example, only apply to certain crash types (i.e., SL-relevant)? That is, if a confounding variable such as safety culture had played a role, then the benefits (i.e., crash rate reductions) would be expected in all crash types. In addition, though not significant, the overall crash rate was in the opposite direction of what would be expected if a confounding variable, such as safety culture, had played a role. As such, the combination of these two results (i.e., a non-significant overall crash rate, but highly significant SL-relevant crash rate) supports the hypothesis that trucks equipped with SLs in the current study were effective in reducing SL-relevant crashes.

Moreover, a second confirmatory analysis was conducted whereby a random effect negative binomial distribution model was developed to model the crash count. Similar to the ANOVA results, a clear benefit was observed with this analysis approach and a significant SL-relevant crash rate reduction was found for trucks equipped with SLs (compared to non-SL trucks). The results from the modeling analysis were profound in that the resulting calculated SL-relevant crash rate ratio (1.94) was approximately twice that for non-SL-equipped trucks compared to trucks with an SL.

4.2 FINAL SUMMARY

Though much has been learned through this study of SL technology for CMVs, the following highlights some key takeaways:

- This study represents the most comprehensive investigation that has ever been conducted on SLs.
- The various analyses conducted used data from more than 138,000 trucks that were involved in more than 15,000 crashes.
- Results from multiple analyses indicated a profound safety benefit for trucks equipped with an active SL.
- The cost of SL technology is negligible and is a standard feature on new trucks (owners only need to activate the device and set the speed limit).
- The positive findings in this study were consistent with the bulk of the literature on this topic indicating significant safety benefits associated with speed reduction which can be achieved through the implementation of SLs. Domain research on the potential drawback of speed deviations among vehicles that could occur due to the interaction of SL-equipped vehicles and those without SLs seems to be far outweighed by the significant safety benefits associated with a reduction in absolute speed afforded by SLs.

APPENDIX A—CONTACTS MADE WITH OTHER ORGANIZATIONS

In conducting this literature review in Phase I, the study team contacted government agencies outside the U.S., seeking further information on SL studies, both published and unpublished. These agencies were queried as to past and current applications, programs, and studies involving the use of SLs; further, these contacts were asked to provide guidance on any other SL safety effectiveness studies.

- VicRoads, Vehicle Safety Department, Australia
  Angus Draheim, Assistant Director (Vehicles and Road Use), Land Transport and Safety Division, Queensland Transport and Main Roads, Australia
- Robert de Maid, Senior Policy Analyst—Safety and Environment, National Transport Commission, Australia
- Pierre Thiffault, Transport Canada
- Doug Switzer, Vice President Public Affairs, Canadian Trucking Alliance, Ontario Trucking Association
- Jean-Paul Repussard, Directorate General Energy and Transport, Unit E3—Road Safety, European Commission
- Anders Godal Holt, ITS and Traffictechnology, Norwegian Public Roads Administration, Vegvesen, Norway
- Mats Hjälm, Senior Administrative Officer, Road Traffic Department, Swedish Road Administration
- Hans Eriksson, Senior Advisor, Commercial traffic department, Swedish Transport Agency
- Ulf Hammerstrom, Mohammed-Reza Yahya, VTI (Swedish National Road and Transport Research Institute)
- Marianne Vanderschuren, Dept. of Civil Engineering, University of Capetown, South Africa
- Robert Haggar, Roadworthiness Team, Department for Transport, U.K.
- Clive Taylor, VOSA Speed Limiter Policy and U.K. Digital Tachograph Risk Manager, Vehicle and Operator Services Agency, Department for Transport, U.K..

[This page intentionally left blank.]

APPENDIX B—FREQUENCY OF TRUCKS WITH AN ONBOARD SAFETY SYSTEM BY YEAR

Table 17. Frequency of Trucks With an Onboard Safety System by Year

Carrier	Without OBSS 2007	Without OBSS 2008	Without OBSS 2009	With OBSS 2007	With OBSS 2008	With OBSS 2009
1	4,197	4,197	4,197	0	0	0
2	0	1	NA	84	84	NA
3	652	648	646	0	0	0
4	6,640	6,483	6,256	0	0	0
5	3,929	4,049	3,968	0	0	0
9	603	582	607	0	0	1
10	4,220	4,165	4,082	0	0	0
11	812	794	782	0	3	0
12	1,621	1,554	1,521	0	0	0
13	NA	NA	423	NA	NA	0
14	16,470	16,294	15,849	0	2	6
17	881	892	872	0	0	0
18	2,337	2,238	2,153	0	0	0
19	179	172	178	128	128	128
20	12	12	11	64	67	68
21	NA	6,024	NA	NA	0	NA
22	NA	2,912	NA	NA	0	NA
23	NA	1,194	NA	NA	0	NA
24	NA	171	NA	NA	0	NA
25	NA	438	NA	NA	0	NA
Total	42,553	52,820	41,545	276	284	203

[This page intentionally left blank.]

APPENDIX C—CRASH FREQUENCY BY YEAR AND CARRIER

Table 18. Crash Frequency by Year and Carrier

SL Status	Carrier ID	Year	Total Crash Frequency	SL-Relevant Crash Frequency	Number of Trucks	Overall Crash Rate*	SL-Relevant Crash Rate*
Non-SL Cohort	3	2007	24	7	652	3.7	1.1
Non-SL Cohort	3	2008	20	5	647	3.1	0.8
Non-SL Cohort	3	2009	18	4	645	2.8	0.6
Non-SL Cohort	21	2008	1,631	486	6,024	27.1	8.1
Non-SL Cohort	22	2008	241	70	2,912	8.3	2.4
Non-SL Cohort	23	2008	82	41	1,194	6.9	3.4
Non-SL Cohort	24	2008	17	4	171	9.9	2.3
Non-SL Cohort	25	2008	47	19	438	10.7	4.3
SL Cohort	1	2007	228	64	4,425	5.2	1.4
SL Cohort	1	2008	189	63	4,386	4.3	1.4
SL Cohort	1	2009	154	30	4,351	3.5	0.7
SL Cohort	2	2007	3	0	84	3.6	0.0
SL Cohort	2	2008	4	2	85	4.7	2.4
SL Cohort	4	2007	875	213	6,601	13.3	3.2
SL Cohort	4	2008	718	171	6,462	11.1	2.6
SL Cohort	4	2009	491	96	6,246	7.9	1.5
SL Cohort	5	2007	1,544	44	3,929	39.3	1.1
SL Cohort	5	2008	1,664	46	4,049	41.1	1.1
SL Cohort	5	2009	1,583	62	3,968	39.9	1.6
SL Cohort	9	2007	55	16	601	9.2	2.7
SL Cohort	9	2008	34	9	582	5.8	1.5
SL Cohort	9	2009	60	29	605	9.9	4.8
SL Cohort	10	2007	264	75	4,215	6.3	1.8
SL Cohort	10	2008	209	91	4,161	5.0	2.2
SL Cohort	10	2009	126	40	4079	3.1	1.0
SL Cohort	11	2007	69	8	809	8.5	1.0
SL Cohort	11	2008	54	7	794	6.8	0.9
SL Cohort	11	2009	39	9	781	5.0	1.2
SL Cohort	12	2007	148	26	1,614	9.2	1.6
SL Cohort	12	2008	81	14	1,553	5.2	0.9
SL Cohort	12	2009	48	7	1,521	3.2	0.5
SL Cohort	13	2009	20	11	422	4.7	2.6
SL Cohort	14	2007	1,023	193	16,430	6.2	1.2
SL Cohort	14	2008	849	168	16,281	5.2	1.0
SL Cohort	14	2009	408	72	15,848	2.6	0.5
SL Cohort	17	2007	35	7	878	4.0	0.8
SL Cohort	17	2008	46	13	891	5.2	1.5
SL Cohort	17	2009	26	6	871	3.0	0.7
SL Cohort	18	2007	978	40	2,337	41.8	1.7
SL Cohort	18	2008	879	38	2,238	39.3	1.7

SL Status	Carrier ID	Year	Total Crash Frequency	SL-Relevant Crash Frequency	Number of Trucks	Overall Crash Rate*	SL-Relevant Crash Rate*
SL Cohort	18	2009	794	40	2,153	36.9	1.9
SL Cohort	19	2007	29	9	306	9.5	2.9
SL Cohort	19	2008	22	7	298	7.4	2.3
SL Cohort	19	2009	28	8	304	9.2	2.6
SL Cohort	20	2007	1	0	76	1.3	0.0
SL Cohort	20	2008	4	0	79	5.1	0.0
SL Cohort	20	2009	4	2	79	5.1	2.5

REFERENCES

American Transportation Research Institute. (in press). *The Role of Speed in Large Truck Safety*. American Transportation Research Institute, Arlington, VA.

American Trucking Associations. (2008). *Ontario Ministry of Transportation Carrier and Enforcement Branch Proposed Regulations on Speed Limiters.* American Trucking Associations, Arlington, VA.

American Trucking Associations. (2009). *Expanding ATA's Safety Agenda: Executive Summary.* American Trucking Associations, Arlington, VA.

American Transportation Research Institute. (2009). *Speed Limiter Research.* American Transportation Research Institute, Arlington, VA.

Australian National Transport Commission. (2006). *Heavy Vehicle Speed Compliance: Draft Proposal and Draft Regulatory Impact Statement*. Australian National Transport Commission, Melbourne, Australia.

Australian National Transport Commission. (2008). *Sharing Responsibility for Heavy Vehicle Speed Compliance.* Available at http://www.ntc.gov.au/NewsDetail.aspx?newsid=252

Baum, H.M., Esterlitz, J.R., Zador, P., and Penny, M. (1991). Different speed limits for cars and trucks: Do they affect vehicle speed? *Transportation Research Record, 1318*, 3-7.

Ballingall, S. (2007). Speed Limiters on Heavy Vehicles in Victoria, Australia. Email Correspondence. VicRoads Vehicle Safety Department.

Bishop, R. (2005). *Intelligent Vehicle Technology and Trends.* Artech House, Norwood, Mass.

Bishop, R., Murray, D.C., McDonald, W., Hickman, J.S., and Bergoffen, G. (2008). *Safety Impacts of Speed Limiter Device Installations on Commercial Trucks and Buses*. Transportation Research Board, Washington, DC.

Canadian Trucking Alliance. (2006). News Release: Canadian Trucking Alliance Wants to Put the Brakes on Speeding Trucks. For Release on March 2, 2006.

Cantor, D.E., Corsi, T.M., and Grimm, C.M. (2006). Safety technology adoption patterns in the U.S. motor carrier industry. *Transportation Journal, 45,* 20-45.

Comte, S. L. (1996). *Response to automatic speed control in urban areas: A simulator study.* ITS

Working Paper 477, Institute for Transport Studies, University of Leeds.

Comte, S., Wardman, M., and Whelan, G. (2000). Drivers' acceptance of automatic speed limiters: Implications for policy and implementation. *Transport Policy, 7,* 259-267.

Dang, J. (2004). *Preliminary Results Analyzing the Effectiveness of Electronic Stability Control Systems.* Report# DOT-HS-809-790. National Highway Traffic Safety Adminstration, Washington, D.C.

Elvik, R. (2004, November). *Speed, speed cameras and road safety evaluation research.* Paper presented at the meeting of the Royal Statistical Society.

Elvik, R., Christensen, P., and Amundsen, A. (2004). *Speed and Road Accidents*. The Institute of Transport Economics (TOI report 740/2004), Oslo, Sweden.

Evans, L. (1991). *Traffic Safety and the Driver.* Van Nostrand Reinhold, New York, NY.

Federal Motor Carrier Safety Administration (2006). *Report to Congress on the Large Truck Crash Causation Study.* Federal Motor Carrier Safety Administration, Washington, DC.

Federal Motor Carrier Safety Administration (2007a). *Strategy: Saving Lives through Safety, Innovation and Performance.* Federal Motor Carrier Safety Administration, Washington, DC.

Federal Motor Carrier Safety Administration (2007b). *Large Truck Crash Causation Study. LTCCS Summary. Report No. FMCSA-RRA-07-017.* Federal Motor Carrier Safety Administration, Washington, DC.

Fuetsch, M. (2009). Soft enforcement of limiters under way for all truck drivers in Ontario, Quebec. *Transport Topics, 3828,* 2.

Gillam, T. (2006). Ontario, Quebec plans advance to impose truck-speed limiters. *Transport Topics, 3696,* 30-31.

Guerrero, T. (2006). Ontario's plan for engine governors bad for U.S. carriers, execs say. *Transport Topics,* 3677, 21–22.

Hammerstrom, U., and Yahya, M. (2007). *Speed Regulator and Fuel Consumption of Heavy Trucks with Trailer – Result of Reducing Maximum Speed from 89 to 85 kph.* Swedish National Road and Transport Research Institute, VTI notat 32-2006.

Harkey, D.L. and Mera, R. (1994). *Safety Impacts of Different Speed Limits on Cars and Trucks.*

Publication No. FHWA-RD-93-161. Federal Highway Administration, Washington, DC.

Hayes, W. L. (1994). Statistics (5th ed.). Harcourt Brace and Company, Orlando, FL.

Houser, A., Murray, Shackelford, S., Kreeb, B, and Dunn, T. (2009). *Analysis of Benefits and Costs of Lane Departure Warning Systems for the Trucking Industry*. Federal Motor Carrier Safety Administration, Washington, DC.

Hickman, J.S., Knipling, R.R., Olson, R.L., Fumero, M.C., Blanco, M., and Hanowski, R.L. (2005). *Phase I: Preliminary Analysis of Data Collected in the Drowsy Driver Warning System Field Operational Test.* Contract No. DTNH22-00-C-07007, Task Order No. 21. Federal Motor Carrier Safety Administration, Washington, DC.

Insurance Institute for Highway Safety (2003). Faster travel and the price we pay. *Special Issue: Speeding. Insurance Institute for Highway Safety, 38.*

Insurance Institute for Highway Safety (2007a). Good news about teen drivers. *Insurance Institute for Highway Safety Status Report, 42.*

Insurance Institute for Highway Safety (2007b). *Devices to Limit the Speed of Certain Trucks Request for Comments.* Docket No. NHTSA-2007-26851. U.S. Department of Transportation, Washington, DC.

Insurance Institute for Highway Safety (2008). Hit a fastball and you might score a run. Hit something in a speeding car and you might land in the hospital or worse. *Special Issue: Speed. Insurance Institute for Highway Safety, 43*.

Jermakian, J.S. (2010). *Crash Avoidance Potential of Four Large Truck Technologies*. Insurance Institute for Highway Safety, Arlington, VA.

Johnson, S.L., and Pawar, N. (2005). *Cost-Benefit Evaluation of Large Truck-Automobile Speed Limit Differentials on Rural Interstate Highways*. U.S. Department of Transportation, Washington, DC.

Johnston, J., and Shapiro, C. (2007). *Comments in Response to Notice and Request for Comments, Motor Vehicle and Carrier Safety Standards.* Docket No. NHTSA-2007-26851. Owner-Operators Independent Drivers Association, Grain Valley, MO.

Klauer, S.G., Sudweeks, J., Hickman, J.S., and Neale, V.L. (2006). *How Risky is it? An Assessment of the Relative Risk of Engaging in Potentially Unsafe Driving Behaviors*. American Automobile Association Foundation for Traffic Safety, Washington, DC.

Kloeden, C.N., Ponte, G., and McLean, A.J. (2001). *Traveling Speed and the Risk of Crash Involvement on Rural Roads.* Department of Transport and Regional Services Australian Transport Safety Bureau: Road Accident Research Unit, Adelaide University.

Liu, G., and Tate, J. (2004). *Network effects of intelligent speed adaptation systems*. *Transportation, 31*, 297-325.

Lord D, Mannering F. (2010). The statistical analysis of crash-frequency data: A review and assessment of methodological alternatives. *Transportation Research Part A: Policy and Practice*;44(5):291-305.

Makinen, T. and Varhelyi, A. (2001). Field trials with in-car speed limiter. *Transportation Research Part C, 9*, 191-211.

McDonald, W., and Brewster, R. (2007). *Survey of Motor Carriers on Issues Surrounding the Use of Speed Limiting Devices on Large Commercial Vehicles.* American Transportation Research Institute, Arlington, VA.

Murray, D., Shackelford, S., and Houser, A. (2009a). *Analysis of Benefits and Costs of Forward Collision Warning Systems for the Trucking Industry*. Federal Motor Carrier Safety Administration, Washington, DC.

Murray, D., Shackelford, S., and Houser, A. (2009b). *Analysis of Benefits and Costs of Roll Stability Control Systems for the Trucking Industry*. Federal Motor Carrier Safety Administration, Washington, DC.

Muster, T. (2000). *Fuel Saving Potentials and Costs Considerations for U.S. Class 8 Heavy Duty Trucks Though Resistance Reductions and Improved Propulsion Technologies until 2020*. Energy Laboratory, MIT Cambridge, #MIT EL 00-001.

National Highway Traffic Safety Administration. (1987). *Heavy Truck Safety Study.* Report No. DOT-HS-807-109. National Highway Traffic Safety Administration, Washington, DC.

National Highway Traffic Safety Administration. (1991). *Commercial Motor Vehicle Speed Control Safety.* Report to Congress, DOT-HS-807-725. National Highway Traffic Safety Administration: Washington, DC.

National Highway Traffic Safety Administration. (2007a). *Large Truck Crash Facts.* National Highway Traffic Safety Administration, Washington, DC. Available at http://www-nrd.nhtsa.dot.gov/Pubs/811017.PDF

National Highway Traffic Safety Administration. (2009). *Traffic Safety Facts 2008: Speeding*. Retrieved on August 22, 2005 from: http://www-nrd.nhtsa.dot.gov/Pubs/811166.pdf

Office of Motor Carrier Safety. (1999). *Analysis Brief: Speeding-Related Multi-Vehicle Fatal Crashes Involving Large Trucks.* Publication No. MCRT-00-004. Office of Motor Carrier Research and Standards, Washington, DC.

Organisation for Economic Co-Operation and Development and European Conference of Ministries of Transport. (2006). *Transportation Research Centre: Speed Management.* ISBN 92-821-0377-3. Organisation for Economic Co-Operation and Development (OECD) and European Conference of Ministries of Transport (ECMT).

Owner-Operator Independent Drivers Association. (undated). *Imposing speed limiting technology on America's trucks – Hurting small businesses, highways, and the economy.* Available at http://www.ooida.com/MediaCenter/Press_Releases/PDFs/SpeedLmtr-facts.pdf

Owner-Operator Independent Drivers Association. (2007). *Speed Limiter Survey Results Final Report.* Owner-Operator Independent Drivers Association, Grain Valley, MO.

Patterson, T.L., Frith, W.J., Povey, L.J., and Keall, M.D. (2002). The effect of increasing rural interstate speed limits in the United States. *Traffic Injury Prevention, 3*(4), 316-320

Repussard, J-P. (2007). Study on speed limiters. Email Correspondence. European Commission Directorate General Energy and Transport, Unit E3-Road Safety.

Roads and Traffic Authority, NSW. (2005). Speeding research crash risk. Retrieved: November 4, 2005, from: http://www.rta.nsw.gov.au/roadsafety/speedandspeedcameras/speedingresearch.html.

Rothman, K.J., Greenland, S., and Lash, T.L. (2008). *Modern Epidemiology* (3rd ed.). Lippincott Williams and Wilkins, Philadelphia, Pennsylvania.

Royal Society for the Prevention of Accidents. (2001). *Response to the DTLR's Invitation to Comment on the European Commission Proposals for Speed Limiters on Commercial Vehicles.* Royal Society for the Prevention of Accidents: Birmingham, U.K.

Svedlund, J. (2002). ISA in daily life. *Proceedings of the ITS World Congress.* Beijing, China.

Svedlund, J. (2009, June). Personal communication with R. Bishop. Swedish Road Administration ITS Office.

Thiffault, P. (2009a). *Safety implications of mandating speed limiters for motor carriers in Canada.* Currently unpublished. Transport Canada: Ottawa, Canada.

Thiffault, P. (2009b). *SPEED: Section 1: Speed and safety (first draft).* Currently unpublished. Transport Canada: Ottawa, Canada.

Toledo, T., Albert, G., and Hakkert, S. (2007). A simulation-based evaluation of the impact of active speed limiters on traffic flow and safety. *Transportation Research Record, 2019*, 169-180.

Transport Canada. (2007, November). Technical Considerations: Questionnaire Responses from Trucks and Engine Manufacturers Associations Regarding Heavy Truck Speed Limiters. Public letter to Transport Canada. Transport Canada No. TP14809 E. Transport Canada, Ottawa, Canada.

Transport Canada. (2007a). *Final Report: Environmental Benefits of Speed Limiters for Trucks Operating in Canada.* Transport Canada No. TP-14811. Transport Canada, Ottawa, Canada.

Transport Canada. (2007b). *Final Report: Trade and Competitiveness Assessment of Mandated Speed Limiters for Trucks Operating in Canada.* Transport Canada No. TP-14813. Transport Canada, Ottawa, Canada.

Transport Canada. (2008a). *Final Report: Learning from Others: An International Study on Heavy Truck Speed Limiters.* Transport Canada No. TP-14810. Transport Canada, Ottawa, Canada.

Transport Canada. (2008b). *Safety Implications of Mandated Truck Speed Limiters on Canadian Highways*. Transport Canada No. TP-14807. Transport Canada, Ottawa, Canada.

Transport Canada. (2008c). *Speed Limiter Case Study and Industry Review. Final Report.* Transport Canada No. TP-1002769. Transport Canada, Ottawa, Canada.

Transport Canada. (2008d). *Summary Report: Assessment of a Heavy Truck Speed Limiter Requirement in Canada.* Transport Canada No. TP-14808. Transport Canada, Ottawa, Canada.

Transportation Research Board. (2008). *CTBSSP Synthesis 16: Safety Impacts of Speed Limiter Device Installations on Commercial Trucks and Buses.* Transportation Research Board, Washington, DC.

U.K. Department for Transport. (2008). Transport Statistics Bulletin: Road Statistics 2007: Traffic Speeds and Congestion. *Transport Statistics Bulletin, 08,* 20.

Van Loon, A., and Duynstee, L. (2001). *Intelligent Speed Adaptation (ISA): A Successful Test in the Netherlands*. Ministry of Transport, Transport Research Centre (AVV), The Netherlands.

Varhelyi, A. and Makinen, T. (2001). The effects of in-car speed limiters: Field studies. *Transportation Research Part C, 9,* 191-211.

Vermeulen, J. and Klimbie, B. (2002). Resultaten van een praktijkproef met nelheidsbegrenzing van bestelauto's en lichte vrachtauto's. Delft, the Netherlands, 2002, p. 3.

Waller, J.A. (1987). Injury: Conceptual shifts and prevention implications. Annual Review of Public Health, 8, 21-49.

West, B.H., McGill, R.N., Hodgson, J.W., Sluder, S.S., and Smith, D.E. (1997). *Development and Verification of Light-Duty Modal Emissions and Fuel Consumption Values for Traffic Models*, Washington, D.C.

[This page intentionally left blank.]