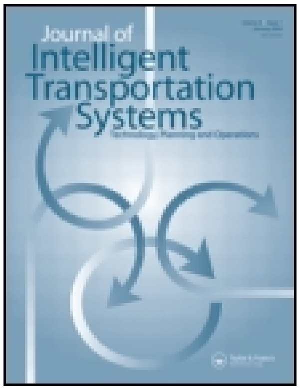

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Safety Benefits of Speed Limiters in Commercial Motor Vehicles Using Carrier-Collected Crash Data

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The purpose of this study was to identify the safety impacts of speed limiters in commercial truck fleets. The primary safety analysis was a focus on the reduction in truck crashes that could have been avoided or mitigated with an active speed limiter installed on the truck. This was the first study to use actual truck crash data collected directly from commercial truck fleets, representing a wide array of crashes. The study included data from 20 commercial truck fleets, including approximately 138,000 truck-years and more than 15,000 truck crashes, as they operated under real-world, revenue-producing deliveries. The findings showed strong positive benefits for speed limiters. Results indicated that trucks equipped without speed limiters had a significantly higher speed limiter-relevant crash rate (approximately 200%) compared to trucks with speed limiters. The cost of the technology is negligible and would not be expected to be cost-prohibitive for commercial truck fleets/owners. The current study went further than any prior research conducted in this domain and provides important data on the efficacy of speed limiters in reducing speed limiter-relevant crashes.

Keywords Crashes; Safety; Speed; Speeding; Speed Governor; Speed Limiter; Truck

INTRODUCTION

Speeding (i.e., exceeding the speed limit or driving too fast for conditions) was a contributing factor in 8% 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% of all large truck crashes and 10.4% of large truck/passenger car crashes were coded as "traveling too fast for conditions" (Federal Motor Carrier Safety Administration, 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 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 et al. (2002) on the repeal of the National Maximum Speed Limit in 1996 supported Evans's (1991) data. Patterson et al. (2002) found that 23 states raised their rural interstate posted 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 posted 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 posted 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 posted speed limits.

Similarly, a rigorous meta-analysis conducted by Elvik, Christensen, and Amundsen (2004) included 97 different studies with a total of 460 estimates on the relationship between changes in speed and changes in the frequency of crashes or

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associated injuries and fatalities. Using the Power Model, Elvik et al. (2004) 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, these data suggest that speed is likely to be the single most important determinant in the frequency of traffic fatalities (e.g., 10% change in the mean speed of traffic is likely to reduce fatal traffic crashes by 34% and have a greater impact on traffic fatalities than a 10% change in traffic volume).

Speed Limiters in Commercial Motor Vehicles

One technology used by commercial truck fleets to lower the overall top speed of their trucks is a speed limiter (SL). SLs (also referred to as speed governors) are devices that interact with a truck engine to only permit the attainment of a preprogrammed maximum speed (e.g., the truck cannot exceed a preset speed of 65 mi/h unless the truck is traveling down a grade). Many commercial truck fleets use SLs to increase safety as well as to increase fuel efficiency, increase engine and brake life, and reduce tire wear. A synthesis by Bishop et al. (2008) on the safety impacts of SLs in commercial trucks and buses found mixed support for the use of these devices in reducing truck crashes.

Although SLs have been mandated in European trucks for more than 10 years and many U.S. fleets have SLs installed on their trucks, there have been few empirical studies that assessed the safety effectiveness of SLs on trucks (Transport Canada, 2008a). Transport Canada (2008a) reported the crash involvement rate for speed-limited heavy trucks in the United Kingdom fell by 26% between 1993 (when SLs were mandated) and 2005. Although authorities noted that other contributing factors may have influenced the decline, they concluded that SLs played a significant role in this reduction. Opponents of SLs argue that safety can be compromised since speed-limited trucks 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 (Johnson & Shapiro, 2007). From a safety perspective, slowing down large trucks may result in lower travel risks for all motorists on the road, as it possibly reduces crashes and mitigates the severity of crashes.

Overview of the Current Study

This study assessed the safety benefits of SLs on commercial trucks as they operated during normal revenue-producing deliveries (under real-world driving pressures and situations). Although other studies have assessed the safety benefits of SLs in cars (Comte, 1996; Makinen & Varhelyi, 2001; Van Loon & Duynstee, 2001), using simulations (Liu & Tate, 2004; Toledo, Albert, & Hakkert, 2007; Transport Canada, 2008b), and crash rates in differential posted speed limits (Baum et al., 1991; Harkey & Mera, 1994; Johnson & Pawar, 2005), this study used real-world data collected from commercial truck fleets. The approach used in this research went far beyond any previous study in this domain. Although speed limiters are not traditionally conceptualized as "intelligent" safety systems, the results from the current can be used to model the safety benefit of intelligent speed adaptation systems that are currently being considered for use in European countries.

METHOD

This study collected crash data from 20 commercial truck fleets in calendar years 2007, 2008, and 2009. Some fleets did not provide crash records for all three calendar years or information on each truck's mileage (i.e., exposure); thus, the data set was unbalanced and the number of trucks per year (truck-years) was used as an exposure measure. In the absence of mileage, the use of a truck-based measure of exposure is acceptable. For example, the 2008 Traffic Safety Facts uses both mileage and vehicles as measures of exposure (NHTSA, 2009). All trucks in the current study were Class 7 or Class 8 trucks.

Data Reduction

Although this study was similar to studies that have assessed the effectiveness of onboard safety systems (OBSS), such as forward collision warning, studies that assess OBSSs target specific crash types that could have been prevented or mitigated by the specific OBSS (see Dang, 2004; Houser et al., 2009; Jermakian, 2010; Murray, Shackelford, & Houser, 2009a, 2009b). For example, an analysis on the safety benefits of forward collision warning would assess the reduction in truck-striking rear-end crashes. However, a speeding truck is associated with 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 or preventing truck crashes (i.e., highways with a posted speed limit of 97 km/h or 60 mi/h or greater). No trucks in the current study had an SL setting of less than 97 km/h (60 mi/h).

Trained research personnel, who were crash data-set domain experts and were blind to the SL status of each commercial fleet, reviewed several data elements included in the crash file to determine if the crash was an "SL-relevant crash." A SL-relevant crash was a crash where an active SL would be most effective in mitigating or preventing high-speed [posted speed limit 97 km/h (60 mi/h) or greater] truck crashes on highways. An SL-relevant crash was primarily determined by assessing four different variables in the crash file. This was necessary as the carrier data set did not include information on the truck's speed at the time of the crash.

The first variable data analysts reviewed to determine if the truck crash was a SL-relevant crashes 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 to be considered a SL-relevant crash. Several carriers listed the posted speed limit at the time of the crash, whereas 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. Moreover, highway locations such as truck stops and entrance/exit ramps were excluded as it is unlikely an SL would have a benefit in these locations (as 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), and 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 in Table 1.

The third variable was the contributing factor(s) in the crash. The contributing factor variable was used to exclude crashes where speed was clearly not a factor in the crash, such as weather-related (e.g., ice, rain, etc.), mechanical-related (e.g., brake failure, tire blowout, etc.), and driver nonperformance errors (e.g., asleep, intoxicated, etc.). Note that animal strikes and objects in the roadway were excluded as SL-relevant crashes, as most carriers train their drivers to avert an avoidance maneuver in these circumstances (as the avoidance maneuver would be more dangerous than striking the animal and/or object). The three variables above were used to automatically filter the data set. Research personnel reviewed the crash narrative in the remaining crashes, based on the filtering by location/posted speed, crash type, and contributing factor. 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 Table 2 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 an SL-relevant crash could contain one or more of these keywords.

All the data elements (i.e, variables) in the crash files were reviewed by data analysts in order to determine whether the crash was an 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 (interrater reliability was 97.8% and intrarater reliability was 98.4%). Once research personnel completed their review of each crash, the database was merged into a SAS file for analysis.

Table 1 Crash types associated and not associated with an SL-relevant crash (V1 is the participating carrier's truck).

Crash types associated with an SL-relevant crash	Crash types not associated with an SL-relevant crash
V1 into rear of V2	V1 hit by unknown vehicle
V1 wrong side of road	V1 left or right turn squeeze on V2
V2 wrong side of road	V1 lost wheel
V1 passing V2	V1 or V2 ran stop sign or yield sign
V2 passing V1	V1 left or right turn
V1 changed lanes	V1 U-turn
V2 changed lanes	V1 pulling away from curb
V1 into stationary object	V1 (V2) into parked V2 (V1)
V1 ran off road	V1 backing
V1 hit pedestrian	V1 rollaway
V1 overturn	V1 loading or unloading
V1 jackknife	V2 backing
V2 hit object in roadway	V1 or V2 pulling away from dock
V1 out of control	V2 rollaway
V2 stopped in roadway	V1 wreckered, not DOT recordable
V2 hit by V1	Hooking/unhooking
V1 hit V2	Disputed sign or signal
Sideswipe—merge	Dropped TRL or TRK-TRL collision
Sideswipe—opposite	V2 into rear of V1
Misc. unavoidable	V1 hit viaduct/underpass, animal, object in road
Misc. avoidable	V2 out of control
	Load shift
	Hit by unknown object or moving object
	R/R crossing

Analysis Approach

There were two levels of exposure status in the study design: trucks with an active SL (yes), or trucks without an active SL

Table 2 Keywords used to exclude SL-relevant crashes.

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

(no). More specifically, SLs were considered to improve safety if the trucks with an active SL have a lower SL-relevant 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, SL-relevant crashes involving a truck with an active SL are identified first. Subsequently, a group of trucks without SL-relevant 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). The case-control study is more likely to be biased. This bias is caused by improper control selection; however, this approach can be cost-effective for rare safety events (such as SL-relevant crashes). As it was possible to collect the SL status in all trucks in the current study, the cohort study was preferred (Rothman, Greenland, & Lash, 2008).

The current study followed a retrospective cohort design approach, based on whether an SL was equipped/activated. The trucks were divided into two groups: SL cohort and non-SL cohort. The cohorts reflect trucks with an active SL versus trucks without an active SL; however, there were no trucks in a SL carrier that contained non-SL trucks (or vice versa for non-SL carriers). However, the data collected in the current study reflected fleet-wide use or nonuse of an SL (i.e., all the trucks in a specific carrier had an active SL or vice versa). In each cohort the safety outcomes in a specific study period were collected from crash files obtained from the participating commercial fleets. The safety benefits of SLs were assessed by comparing the outcomes in the two cohorts.

RESULTS

Carrier Demographics

The current study collected data from 20 commercial fleets; six carriers did not have trucks with an active SL (non-SL cohort) and 14 carriers had trucks commercial fleets with an active SL (SL cohort). The size of the participating fleets varied from less than 100 power units to more than 5,000 power units. Exact power unit frequencies are not reported, to protect the fleets' anonymity. All fleets used a "pay per mile" driver compensation method. Only a limited number of carriers reported trucks equipped with some type of OBSS (the total number of power units with an OBSS was less than 1,000 power units in any given calendar year). All participating fleets reported being one of three types of trucking operations: for-hire less-than-truckload (LTL), for-hire truck load (for-hire TL), and a mixture of for-hire TL, for-hire LTL, owner-operator, and independent contractor. Five out of six fleets in the non-SL cohort were listed as mixture of operations and one was listed as for-hire TL, whereas the majority of fleets in the SL cohort (11 out of 14) were for-hire LT and the remaining three fleets were a mixture of operation types.

Crash Analyses

The final data set contained a total of 138,075 truck-years (125,392 in the SL cohort and 12,683 in the non-SL cohort). Truck-years do not reflect the number of mutually exclusive trucks over the three calendar years (as the same truck could be counted in each year), but rather the number of trucks over the three years of data collection. There were in total 15,866 crash records. Approximately 15% of the crashes were identified as SL-relevant crashes (2,372 out of 15,866). The safety impact of SLs was evaluated by the SL-relevant crash rate, which was defined as the ratio of crashes divided by the number of truck-years multiplied by 100. Thus, the unit of the SL-relevant crash rate was the frequency of SL-relevant crashes per 100 trucks/year (e.g., a SL-relevant crash rate of 10 would indicate that 10 crashes would occur for every 100 trucks each year).

As 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 mean overall crash rate and SL-relevant crash rate across carriers and years in the SL cohort (black bar) and non-SL cohort (gray bar) are shown in Figure 1. What is interesting about Figure 1 is 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 analysis of variance 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; $F_{(1,45)} = 6.5$, $p = .014$). The mean crash rate is the average of crash rates by fleet and year. A review of the crash files by data analysts indicated the criteria for inclusion as a crash file in a participating fleets' database were quite different among fleets. Some fleets only included major crashes (e.g., significant property or vehicle damage), and other fleets included all types of crashes, including minor crashes (e.g., truck drove over bush, truck scraped mirror against a building, etc.). This makes interpretation of the overall crash rate very difficult; however, the SL-relevant crashes identified by data analysts had a consistent operational definition across fleets and most of these crashes were skewed toward more severe crashes.

To further quantitatively evaluate the safety effects of SLs, the research team used a negative binomial regression model to model the SL-relevant crash count, which is the state-of-practice in modeling accident frequency (Lord & Mannering, 2010). It is particularly suitable for overdispersion data where the Poisson

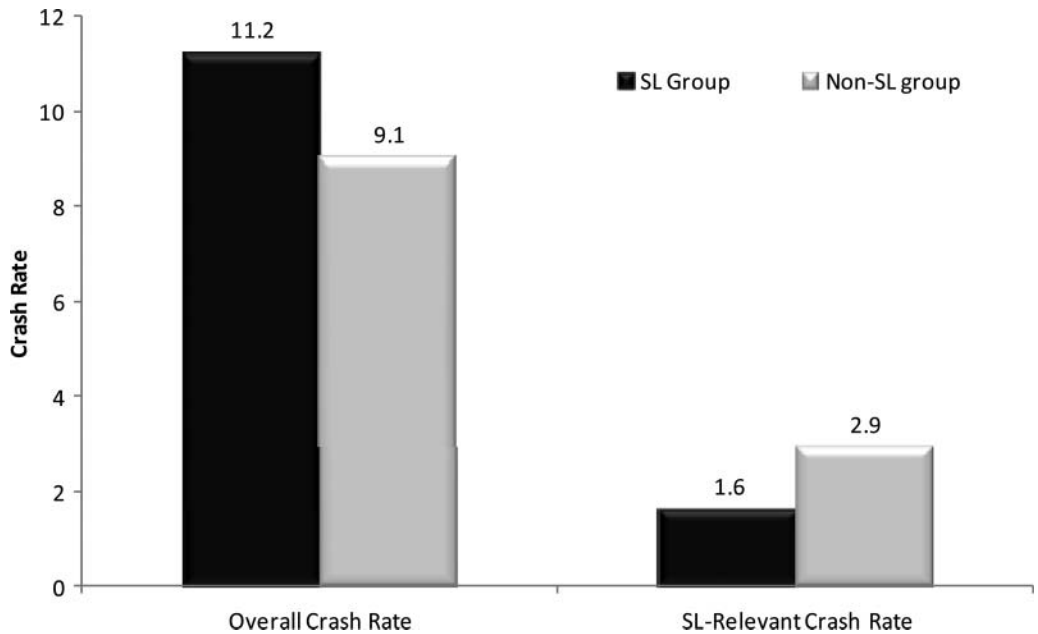

Figure 1 Average overall crash rate and SL-related crash rate in the SL and non-SL cohorts.

regression model, another commonly used approach, cannot fit these data well. The model, $Y_{ij} \sim$ Negative Binomial (μ_{ij}, k), was comprised of the following: Let Y_{ij} be the number of SL-relevant crashes for carrier i in the jth year. Note that Y_i is assumed to follow a negative binomial distribution, where μ_{ij} is the expected number of SL-relevant crashes for carrier i in year j and k is an overdispersion parameter. The variance is $\mu + k\mu^2$. The mean μ is assumed to be affected by the number of trucks in the carrier and the presence of an active SL. The model, $\log(\mu_{ij}) = log(E_{ij}) + X_{ij}\ \beta + \alpha_i$, is comprised of the following: E_{ij} is the number of trucks in carrier i in year j, X_{ij} is the vector of covariate, β is the regression coefficient, and α_i is a random effect associated with carrier i. The random intercept (α_i) incorporated the effects that some carriers contributed multiple calendar years of data. The serial correlation was not included in the analysis; however, it is believed that not including the serial analysis will not change the overall conclusion of the analysis. The impacts of an active SL can be evaluated by the significance of β. The exponential of β is the ratio of SL-relevant crash rate between non-SL cohort and SL cohort.

Table 3 shows the modeling fit statistics as well as the estimates for the covariance parameters. The generalized chi-squared value over degrees of freedom was close to "1.0" (0.96) and showed no evidence of lack of fit. The relatively large overdispersion parameter (0.096 with a standard error of 0.037) indicated the presence of overdispersion and is in support of the negative binomial model. Table 3 also provides the mean and standard error for the random intercept (0.229, standard error 0.106), which shows considerable variation among carriers. Table 4 shows the estimation for the effects of the SL cohort from the mixed-effect model. The presence of an SL showed a significant association with the SL-relevant crash rate (p = .0295), which is consistent with the simple analysis of variance (ANOVA) just described. The estimated SL-relevant crash rate ratio was 1.94 (95% confidence interval [CI] = 1.07 to 3.49), which indicates the SL-relevant crash rate for carriers in the non-SL cohort was 1.94 times greater than fleets in the SL cohort. Confounding effects could potentially be addressed by including the other factors in the model (e.g., operation type, OBSS, etc.). The lack of a model-based adjustment for confounding is commonly referred as the "omitted-variable bias" in transportation safety research (Load & Mannering, 2010). However, the data collected were highly unbalanced, which makes this approach not feasible.

DISCUSSION

This study assessed the safety benefits of SLs as they operate during normal revenue-producing deliveries. Crash data from 20 carriers representing small, medium, and large carriers hauling a variety of commodities were used. The data from these carriers

Table 3 The mixed effect negative binomial model fitting and covariance parameters estimates.

Model fit statistics	Values	
-2 Res log pseudo-likelihood	79.92	
Generalized chi-squared	43.02	
Generalized chi-squared/degree of freedom	0.96	
Number of observations	47	
Covariance parameter	**Estimate**	**Standard error**
Random Intercept (α_i)	0.229	0.106
Over dispersion parameter (k)	0.096	0.037

Table 4 The effects of SL status on the SL-relevant crash rate estimated from the mixed-effect negative binomial regression.

Label	Regression coefficient estimate	Standard error	p Value	SL-relevant crash rate ratio	95% Confidence interval
Non-SL versus SL (β) Crash rate ratio	0.661	0.288	0.0295	1.94	1.074 to 3.494

included 138,075 truck-years and 15,689 crash records collected over a 3-year period (2007 to 2009). The approach used to assess the safety benefits of SLs in the current study 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). Given the limitations noted in the following section, the results across analyses appear to indicate 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. non-SL, $p = .65$). However, for SL-relevant crashes, there was a strong statistically significant difference in crash rates showing a clear benefit for trucks with an SL ($p = .01$). 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 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 commercial 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).

If this were 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. However, it may also be the case that safety-minded companies may have more complete crash records and so seem to have higher crash rates.

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 in 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 calculated SL-relevant crash rate ratio (1.94) was approximately twice that for non SL-equipped trucks compared to trucks with a SL.

Limitations

There were several limitations and potential caveats in the analyses just noted. Most of the caveats and limitations reflect uncertainty in the availability and quality of data provided by participating carriers. More specifically, some participating carriers provided detailed crash files, and other participating carriers only submitted limited information in their crash files. One significant caveat was the operational definition of a SL truck crash. Ideally, the safety evaluation should be based on truck crashes that could have been avoided or mitigated with an active SL installed on the truck. Data were needed on the truck's speed at the time of the crash to provide a high likelihood of such a situation. Only two of the participating carriers provided some information on the speed of the truck at the time of the crash, and this was via driver self-report. The truck crashes in the current study that were termed an "SL-relevant crash" were elicited through review of the crash files by trained data analysts. Thus, there are likely to be misclassifications by following the operational definition of a SL crash noted here. These misclassifications or false positives could affect the validity of the results and the conclusions that follow. Although the current study had two independent reviews assess each crash file to determine if the truck crash was related to the SL, this inter- and intrarater reliability only assessed if research analysts were following the operational definition and did not assess the validity of the actual truck crash being a SL crash. Also, participating fleets did not have information on whether the SL had been tampered with or deactivated in some way. Thus, some trucks in the SL cohort (and their associated crashes or noncrashes) should have been in the non-SL cohort.

REFERENCES

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

Bishop, R., Murray, D. C., McDonald, W., Hickman, J. S., & Bergoffen, G. (2008). *Safety impacts of speed limiter device installations on commercial trucks and buses*. Washington, DC: Transportation Research Board.

Comte, S. L. (1996). *Response to automatic speed control in urban areas: A simulator study*. ITS Working Paper 477. Leeds, UK: Institute for Transport Studies, University of Leeds.

Dang, J. (2004). *Preliminary results analyzing the effectiveness of electronic stability control systems*. Report number DOT-HS-809–790. Washington, DC: National Highway Traffic Safety Adminstration.

Elvik, R., Christensen, P., & Amundsen, A. (2004). *Speed and road accidents*. Oslo, Sweden: Institute of Transport Economics (TOI report 740/2004).

Evans, L. (1991). *Traffic safety and the driver*. New York, NY: Van Nostrand Reinhold.

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

Harkey, D. L., & Mera, R. (1994). *Safety impacts of different speed limits on cars and trucks*. Publication no. FHWA-RD-93–161. Washington, DC: Federal Highway Administration.

Houser, A., Murray, Shackelford, S., Kreeb, B, & Dunn, T. (2009). *Analysis of benefits and costs of lane departure warning systems for the trucking industry*. Washington, DC: Federal Motor Carrier Safety Administration.

Jermakian, J.S. (2010). *Crash avoidance potential of four large truck technologies*. Arlington, VA: Insurance Institute for Highway Safety.

Johnson, S. L., & Pawar, N. (2005). *Cost-benefit evaluation of large truck-automobile speed limit differentials on rural interstate highways*. Washington, DC: U.S. Department of Transportation.

Johnston, J., & Shapiro, C. (2007). *Comments in response to notice and request for comments, Motor vehicle and carrier safety standards*. Docket no. NHTSA-2007–26851. Grain Valley, MO: Owner-Operators Independent Drivers Association.

Liu, G., & 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., & Varhelyi, A. (2001). Field trials with in-car speed limiter. *Transportation Research Part C*, **9**, 191–211.

Murray, D., Shackelford, S., & Houser, A. (2009a). *Analysis of benefits and costs of forward collision warning systems for the trucking industry*. Washington, DC: Federal Motor Carrier Safety Administration.

Murray, D., Shackelford, S., & Houser, A. (2009b). *Analysis of benefits and costs of roll stability control systems for the trucking industry*. Washington, DC: Federal Motor Carrier Safety Administration.

National Highway Traffic Safety Administration. (2009). *Traffic safety facts 2008: A compilation of motor vehicle crash data from the fatality analysis reporting system and the general estimates system*. Retrieved from http://www-nrd.nhtsa.dot.gov/pubs/811170.pdf

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

Rothman, K. J., Greenland, S., & Lash, T. L. (2008). *Modern epidemiology* (3rd ed.). Philadelphia, PA: Lippincott Williams & Wilkins.

Toledo, T., Albert, G., & 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. (2008a). *Final report: Learning from others: An international study on heavy truck speed limiters*. Transport Canada No. TP-14810. Ottawa, ON, Canada: Transport Canada.

Transport Canada. (2008b). *Safety implications of mandated truck speed limiters on Canadian highways*. Transport Canada No. TP-14807. Ottawa, ON, Canada: Transport Canada.

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