Update to Issues Report for Interstate Speed Changes

Project 16-11

Final Report

by

Christopher Monsere, P.E. (OR)
Sirisha Kothuri
Ali Razmpa
Portland State University

for

Oregon Department of Transportation
Research Unit
555 13th St NE
Salem, OR 97301-6867

June 2017

This page intentionally blank

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

Currently, the Oregon Department of Transportation is investigating the potential for increasing the truck speed limit from 55 to 60 mph in segments where the current speed limit is 65 for cars/light vehicles and 55 mph for trucks. This report summarizes the literature on the operational and safety impacts of raising speed limits, the effect of uniform versus differential speed limit policies, and truck equipment and work zone policies.

1.1 SCOPE OF UPDATE

This report updates select topics from a previously published report "Impacts and Issues Related to Proposed Changes in Oregon's Interstate Speed Limits" by Monsere et al. (2004). New topics, including impacts of different prevalent strategies in work zones and truck equipment on vehicle speeds and safety were reviewed. The report reviews literature published since 2004 and indexed on databases such as Transport Research International Documentation (TRID), Web of Science, PubMed, Engineering Compendex, and Google Scholar using a list of keywords. Additionally, the reference lists of a number of key sources were mined to identify additional references.

Table 1-1: Summary of Scope of the Literature Review

Topic	Status	Short Summary of Scope
Current Speed Limits	Update	A review of current speed limits was performed for all states. Also included in the review are type of speed limits (universal or differential) and maximum posted speed limits on interstate facilities by state.
Truck Safety Data	New	A review of truck safety statistics was conducted between 2009 and 2016.
Role of Speed in Crashes	Update	Specific to trucks and large vehicles, a review of updated work on how speed contributes to crashes and how speed limit changes affect overall crash occurrence were documented.
Uniform Speed Limits	Update	Updated review of published work documenting the impacts of uniform speed limits on observed speeds, crash frequency and severity of cars and trucks
Differential Speed Limits	Update	Updated review of published work documenting the impacts of differential speed limits on observed speeds, crash frequency and severity of cars and trucks
Other Factors Influencing Crash Frequency and Severity	New	Review of published work for factors (other than speed) that influence crash frequency and severity
Truck Equipment and Safety	New	A review was conducted to establish literature on truck safety and inspections as it relates to truck speeds.
Vehicle Speeds in Work Zones	New	A review of equipment and strategies used to improve vehicle and truck safety in work zones was conducted and documented

2 LITERATURE REVIEW

This chapter presents a review of current literature published since 2004 for each of the topics to be updated.

2.1 CURRENT INTERSTATE SPEED LIMITS

The authority to set speed limits on interstate facilities rests with state and local governments. These typically range from 60 – 85 mph. Figure 2-1 shows the current maximum speed limits for vehicles on interstate facilities across the US. The maximum may not apply to all roads in each state. While most states utilize uniform speed limits, seven states (California, Idaho, Indiana, Michigan, Montana, Oregon, and Washington) employ differential speed limits (DSL) for trucks.

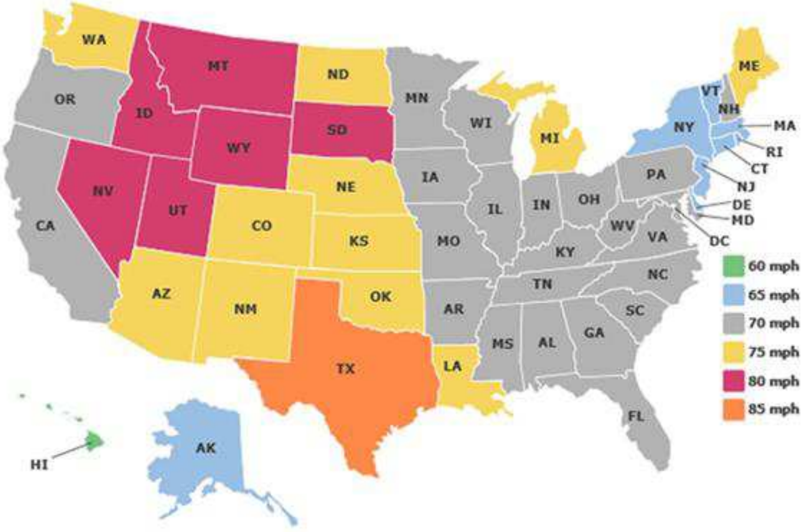


Figure 2-1: Maximum Interstate Speed Limits (Source IIHS)

Table 2-1 shows the detail in the seven states where differential speeds limits for trucks exist. The truck maximum speed limits are between 55- 70 mph and are always lower than posted car speed limits. The differences range from 5 to 15 mph in car and truck speeds.

Gates et al. (2016) tabulated recent changes to speed limit policies in different states. This table is included in the Appendix. Since 2011, 28 states have raised their posted speed limits and three states – Montana, Texas, and Oregon have raised speeds limits for trucks as well.

Table 2-1: States with DSL on Specified Segments of Interstates, (Source IIHS)

State	Rural interstates (mph)			Urban interstates (mph)		
	Car	Truck	Difference	Car	Truck	Difference
California	70	55	15	65	55	10
Idaho	75	70	5	75	65	10
	80	70	10	80	65	15
Indiana	70	65	5	55	55	0
Michigan	70	65	5	70	70	0
	75	65	10			
Montana	80	65	15	65	65	0
Oregon	65	55	10	55	55	0
	70	65	5			
Washington	70	60	10	60	60	0
	75	60	5			

2.2 TRUCK SAFETY DATA

Figure 2-2 shows that the frequency of bus and large truck crashes, fatalities and injuries increased by 35%, 19%, and 22%, respectively, from 2009 to 2015 (FMCSA 2011-16). Figure 2-3 shows the percentage of total truck fatal crashes by posted speed limit. While it would be helpful to know the length of roadway in each speed category to better make comparisons, a general conclusion can be drawn that most truck-involved fatal crashes are on higher speed roadways and that there has been an increase to the percentage of these crashes on 70-75 mph roadways.

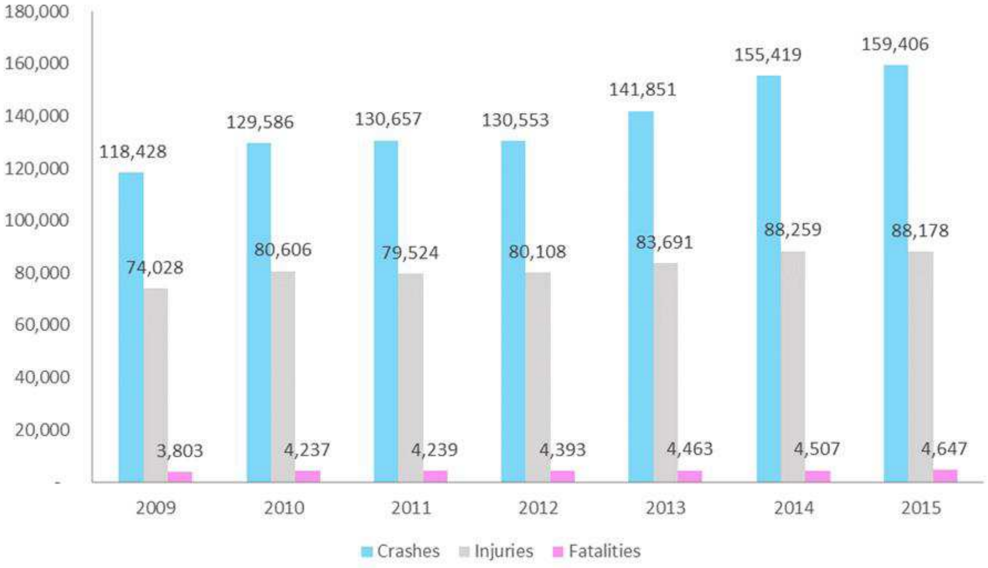


Figure 2-2: Bus and Large Truck Crash Frequencies, Fatalities and Injuries (2009-2016) (FMCSA 2011-2016)

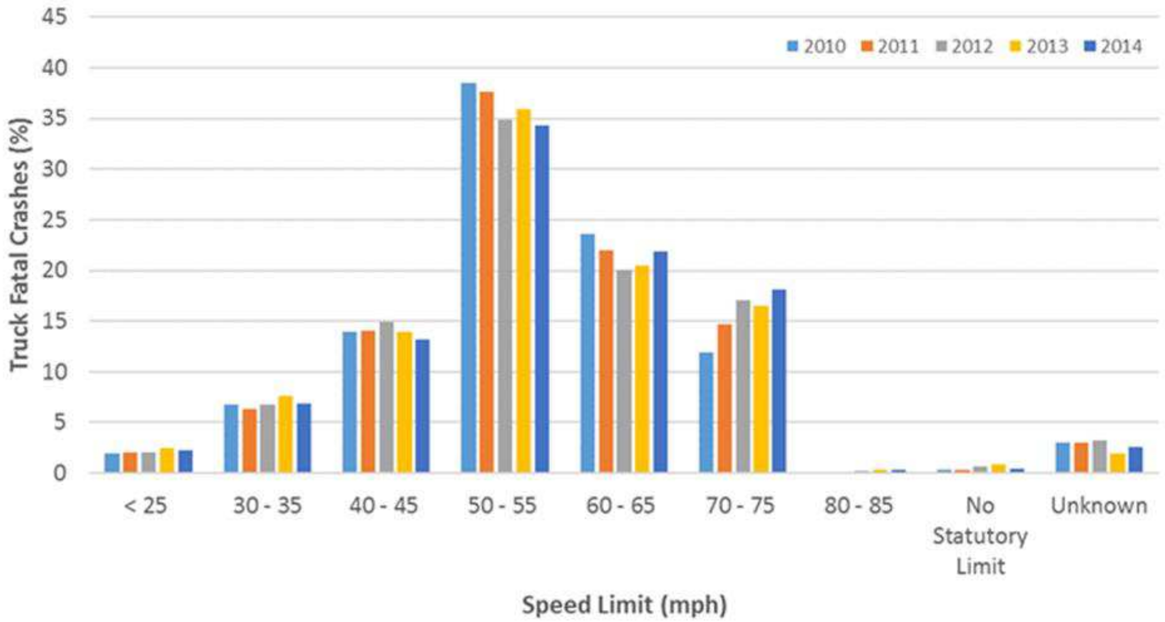


Figure 2-3: Fatal Truck Crashes by Speed Limit (2010-2014)

2.3 ROLE OF SPEED IN CRASHES

In the prior synthesis report, the conclusion was that raising speed limits increases crash fatality rates, particularly on rural interstates, and also increases crash severity. The literature reviewed since then in this report agrees with this conclusion.

Kockelman (2006) conducted a comprehensive study to investigate safety and operational impacts of speed limit changes using a number of data sets including Washington State HSIS data (1993 to 1996) for high-speed roadways, a national driver safety survey, vehicle speed data from Southern California and Austin, Texas, and a national sample of crash records. Statistical methods were used to study the impacts of speed limits on speed choice, crash frequency, and crash severity. It was found that speed limit increases are associated with higher average speeds, and higher speeds are associated with a higher probability of fatalities and serious injuries. Donnell et al. (2009) formulated an informational guideline called speed concept for evaluating design speed and setting speed limits. Crash severity was found to be positively associated with individual vehicle speed, and the probability of being injured in a crash is positively associated with the change in speed at impact. According to Nilsson (cited in OECD), a 5% change in average speed is associated with a change in all injury and fatal crash frequencies by 10% and 20%, respectively (OECD 2006). Aarts and Schagen (2006) reviewed the relationship between driver speed and crash rate in the literature. They found that an increase in individual vehicle speed increases crash rate exponentially and an increase in average road speed increases crash rate by a power function.

Friedman et al. (2006) used FARS data from 1995 to 2005 to investigate the effect of raising speed limits on road fatalities and injuries. After controlling for exposure density (vehicle miles traveled divided by miles of public roads) and vehicle density (number of cars per mile of road), they found that raising speed limits resulted in an average increase of 3.2% in road fatalities, with the highest observed increase on rural interstates at 9.1% (4.0 % on urban interstates). Goodwin and Anderson (2015) found that fatalities increased on Texas interstate highways with 65 mph or greater speed limits by 45% from 1994 to 1999. National trends observed were similar during the same time, with a 45% increase in fatalities on US interstates. However, the ratio of fatalities to VMT actually decreased from 1994 to 1999 for both Texas and national data by 7 and 11 percent, respectively.

Savolainen et al. (2014) conducted a longitudinal analysis of fatal crash data from 1999 to 2011 across the US. They found that higher speed limits were associated with more single-vehicle crashes, while lower speed limits were associated with more rear-end crashes. A state-level assessment of traffic crash data for Michigan freeways from 2004 to 2012 showed that crash, injury, and fatality rates on freeways with higher design speeds (70+ mph) were lower than those on segments where speed limits were raised from 55 to 65 or 70 mph. This research highlights the importance of geometric design and traffic characteristics when considering speed limit increases (and is particularly relevant to the section of freeway being currently considered by the Oregon DOT for changes).

Elvik conducted a meta-analysis in 2004 to develop a model describing the relationship between changes in mean speed and changes in the number of crashes or victims. He combined 460 estimates from 98 studies, many of which controlled for potential confounding factors. Confounding factors included regression to the mean, long-term trends in the number of accidents, changes in traffic volume, changes in risk factors influencing crash occurrence, and other measures influencing road safety. Elvik found that the relationship between changes in mean speed and both crash and victim frequencies is well-described by means of a power function. It was found that the effect of speed on number of crashes and injury severity is greater than other known risk factors, such as volume. Equation 1 defines the power function initially proposed by Nilsson. Assuming an exponent of 4 for fatal crashes, a 10% reduction in mean speed would reduce fatal crashes by 34%, but a 10% reduction in traffic volume would reduce fatal crashes only by 5%- 8% (Elvik 2005; Elvik 2009).

$$\frac{Accident\ after}{Accident\ before} = \left(\frac{Mean\ Speed\ after}{Mean\ Speed\ before}\right)^{Exponent} \qquad (1)$$

Grant and Lilliard (2009) found that higher speed limits were generally associated with higher truck-crash fatality rates. They plotted average large-truck involved fatalities by rural interstate speed limits across the US from 1991 to 2005 (Figure 2-4).

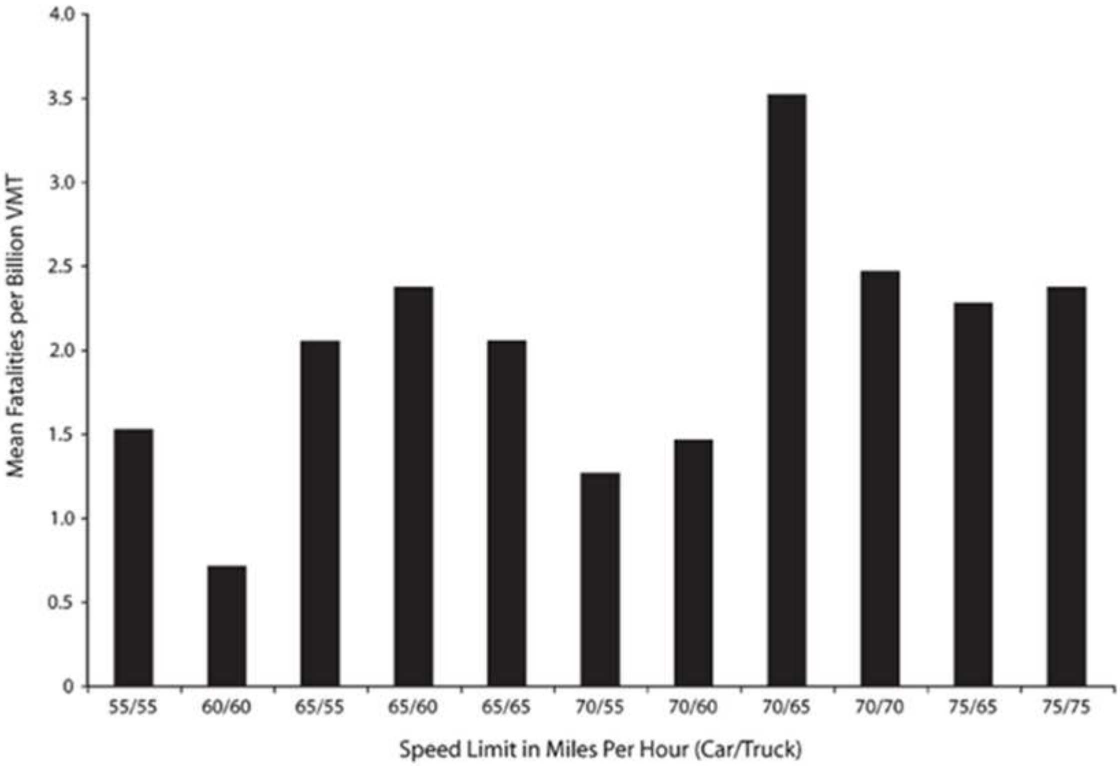


Figure 2-4: Average Large-Truck Involved Fatalities by Rural Interstate Speed Limits across the US (1991-2005), (Grant and Lillard 2009).

Finally, the question of whether maximum speed or the variance in vehicle speeds causes crashes continues to be reviewed. According to Johnson and Pawar (2005), their review of the literature suggests there is a relatively strong consensus among both researchers and practitioners that higher variance in vehicle speed is associated with higher risk of crash (as more interactions occur among vehicles and thus the probability of being involved in a crash increases). It is less clear how this speed variance interacts with changes in the posted speed limit or how speed variance applies specifically to trucks and cars given the size and performance differences of these vehicles. More detail is discussed in the differential speed limit section.

2.4 UNIFORM SPEED LIMITS

2.4.1 Impacts on Observed Speeds

The prior report found that raising speed limits (from 65 to 70 mph) increased average and 85th percentile speed over time (Monsere et al. 2004). The literature reviewed in this report is consistent with this conclusion.

All studies reviewed examined increases to posted speed limits. Recent studies are conclusive in their findings that raising speed limits results in increases in mean and 85th percentile vehicle speeds.

Table 2-2 summarizes the results of these studies. The data indicate that an increase in the speed limit increases mean and 85th percentile speeds by a lesser amount than the speed limit increase (Alemazkoor and Hawkins 2014; Donnell et al. 2016; Retting and Cheung 2008; Retting and Teoh 2008; Johnson and Murray 2010; Gates et al. 2016; Dixon et al. 2012; Savolainen et al. 2014). Kockelman (2006) found that speed limit increases were associated with mean speed increases less than half the increase in the speed limit.

Johnson and Pawar (2005) assessed operational and safety impacts of speed limit policies. They analyzed speed data collected on Oklahoma and Missouri rural interstate highways with 75 and 70 mph speed limits, respectively. . Analysis of speed data showed that Oklahoma with higher speed limits had mean speeds, 85th percentile speeds, and compliance rates larger than Missouri with lower speed limits.Oklahoma with higher speed limit (75 mph) had larger speed car variance and slightly smaller speed truck variance than Missouri with lower speed limit (70 mph). It should be noted that, according to Johnson and Pawar (2005), a number of studies concluded that higher variance in vehicle speed is associated with higher risk of crash, as more interactions occur among vehicles. Results are shown in Table 2-2. They considered strict enforcement, highway design speed, truck percentage, differential speed limits and truck speed limits over 65 mph as other important factors associated with an increase in speed variance. Grant and Lilliard (2009) conducted a cross-sectional time-series regression analysis using state-level data from 1991 to 2005 in the US to estimate traffic fatalities from large truck-involved crashes. They found that higher speed limits, seat belt laws, truck length, diesel fuel consumption, truck volume, income and unemployment rates are significant predictors of truck-crash fatality rates.

Johnson and Murray (2010) compared the effect of different speed limit policies on vehicle speeds across the US. The results of this study indicated that the effect of different posted speed limits on mean and 85th percentile vehicle speed was small. They found that, on average, states with 75 mph car speed limits had only 3.7 mph higher mean car speeds than states with 65 mph car speed limits. The 85th percentile car speed remained on average unchanged between states with 70 mph car speed limits and states with 65 mph car speed limits.

Table 2-2: The Effect of Raising Uniform Speed Limits on Vehicle Speed Measures (Study Results)

No	States	Policy	Before (mph)	After (mph)	85th Percentile Speed Change (mph)	Mean Speed Change (mph)	Compliance Rate Change	Speed Variance (mph)
1	Texas	USL	70	75	+3	< +5		
2	Pennsylvania	USL	65	70	< +5	< +5		
3	Utah	USL	75	80		< +5	Cars (+)	
							Trucks (+)	
4	Ohio	USL*	<65	70				5.4
5	Oklahoma vs. Missouri	USL*$_{(Trucks)}$	70	75	+4	+4	+3.1%	1.08
		USL*$_{(Cars)}$	70	75	+3	+2.2	+21.5%	-0.3

* Comparing speed limits (instead of raising);
1- (Alemazkoor and Hawkins, 2014); 2- (Donnell et al., 2016); 3- (Hu and McCartt, 2014); 4- (Savolainen et al., 2014);
5- (Johnson and Pawar, 2005)

These findings from recent studies agreed with study results from the prior report, which showed that raising speed limits (from 65 to 70 mph) increased average and 85th percentile speed over time (Monsere et al. 2004). Table 2-3 shows the impacts of raising speed limits cited in the prior report. Overall, past and recent study results showed that although an increase in the speed limit is associated with increases in vehicle mean speed and 85th percentile speed, these increases are smaller than the posted speed limit increases.

Table 2-3: Reported Speed Changes for Select States Raising Speeds to 70 mph, (Monsere et al 2004)

Year	Kansas		Minnesota		Washington			Michigan	
	1995	1996	1995	1997	1995	1997	2004	1996	1996
Posted Speed Limit	65	70	65	70	65	70	70	65	70
Average Speed				67.2	66.1	67	68	69	70.4
85th percentile speed	69.5	76.2	73.3	75.0	72.4	74.0	75.0	75.02	75.68
Change from Base Year									
Average Speed		-		-		0.9	1.9		1.4
85th Percentile Speed		6.7		1.7		1.6	2.6		0.66

2.4.2 Impacts on Crash Frequency and Severity

The prior report concluded that raising speed limits is associated with an increase in number of crashes, fatalities and serious injuries (Monsere et al. 2014). The key findings from the recent studies support the findings from the previous study that raising speed limits and larger increases in speed limits are associated with higher crash frequencies and increase in severity.

Davis et al. (2015) found states with a 70 mph speed limit experienced 22% more total fatal crashes than states with 60-65 mph speed limits. States with 75 mph or larger speed limits experienced 84.5% more total fatal crashes than states with 60-65 mph speed limits. Kockelman (2006) found that a 10 mph increase (55 to 65 mph) on a typical high-speed roadway increased total crash counts by about 3%. For a 10 mph increase (55 to 65 mph) in the speed limit, the probability of fatality would be expected to increase by 24%.

Farmer (2016) found that a 5 mph increase in the posted speed limit could be expected to increase fatality rates on interstates and other roads by 8.3% and 4%, respectively. Farmer concluded that the high fatality increase following raised speed limits could considerably reduce positive impacts of other traffic safety strategies. Savolainen et al. (2014) found that a 10 mph increase in speed limits (60 to 70 mph) increased fatalities by 31%, and a 10 mph increase from 65 to 75 mph or greater increased fatalities by 54% from 1999 to 2011 across the US. In Michigan, seven segments raised uniform 55 mph speed limits to 65 or 70 mph speed limits for cars and 60 mph speed limits for large trucks, while adjacent segments with higher design speed maintained uniform 70 mph speed limits. Total and injury crashes increased in the seven freeway segments, but decreased in adjacent segments with higher design speed. Souleyrette et al. (2009) used crash data from 1991 to 2007 (14.5 years before and 2.5 years after the speed limit change) and fit a generalized regression model to time series data. They found that the effect of raising speed limits to 70 mph on crash frequency and injury severity level was not statistically significant on rural Iowa interstates. Study results are summarized in Table 2-4.

Malyshkina and Mannering (2008) concluded that speed limits did not significantly affect the injury severity level of occupants involved in crashes on interstates. They used crash data from 2004 (a year before speed limit increases in July 2005) and from 2006 (a year after speed limit increases) in Indiana. A multinomial logit model was used to determine the injury severity level after raising speed limits up to 70 mph. Analysis of self-reported drivers' free-flow speeds suggested several reasons that could offset the adverse effect of higher travel speed due to increased speed limits on injury severity level: (1) Drivers' average speed became closer to the posted speed limits. (2) The standard deviation of drivers' speeds declined. (3) Drivers' caution increased. (4) Interstates required higher design standards.

Specific to trucks, Davis et al. (2015) found that states with a 70 mph speed limit experienced 31.7% more truck- and bus-involved fatal crashes than states with 60-65 mph speed limits. For states with 75 mph or larger speed limits, truck- and bus-involved fatal crashes were greater by 51.1%. Grant and Lilliard (2009) found that raising either car or truck speed limits increased truck-crash fatality rates significantly.

Table 2-4: The Effect of Raising Speed Limits on Crash Frequency and Severity (Study Results)

Study			Posted Speed Limits (mph)		Changes In Total Crashes		
Reference	**Period**	**Scope**	**From**	**To**	**Fatal Crashes**	**Truck-Related Fatal Crashes**	**Frequency**
Davis et al.	1999-2011	US (Rural)	60-65	70	+22.2 %*	+31.7 %*	
			60-65	75+	+84.5 %*	+51.1 %*	
Kockelman	1993-1996	US	55	65	+24 % **		+3%
Savolainen et al.	1999-2011	US	60	70	+31 %		
			65	75	+54 %		
Grant and Lilliard	2005	US	--	55			-561
			--	75			+362
Farmer	1993-2013	US	+5		+8.3 % **		-33,000

*- Comparing fatal crashes (instead of change from/to); **- Expected change in fatality rate, or probability.

2.5 DIFFERENTIAL SPEED LIMITS

2.5.1 Impact on Observed Speeds

All studies reviewed examined increases in posted speed limits. The prior report found that differential speed limits decreased average truck speeds but increased speed variances between cars and trucks (Monsere et al. 2004). Four of the five recent studies reviewed found that increasing differential speed limits between cars and trucks resulted in an increase in all average speeds, 85th percentile speeds and speed variance for both cars and trucks.

Savolainen et al. (2014) used speed data from 160 freeways locations in Michigan, Indiana, and Ohio with 10 mph differential (70/60 mph), 5 mph differential (70/65 mph), and uniform speed limits (70 or 65 mph), respectively. They developed regression equations to estimate the effect of aforementioned speed limits on speed measures including the mean speed, 85th percentile speed and speed variance, and these measures were separately estimated for cars, bus- and Trucks, and all vehicles. Freeways with speed limits lower than 65 mph were considered as the baseline condition to be compared with other speed limits. Results indicated that three states with different speed limits had higher mean and 85th percentile car speeds than the base condition, and these speed measures were consistent among three states. Mean and 85th percentile bus- and truck speeds were higher than base condition. However higher mean and 85th percentile speeds were lower for buses and trucks than for cars where speed limits were differential (70/60 and 70/65 mph). Standard deviations, where speed limits were uniform (70 or 65 mph) were smallest for cars and insignificant for buses and trucks. In general, cars had larger standard deviations than buses and trucks for different speed limits (USLs or DSLs). With respect to all vehicles, standard deviation was highest (6.9 mph) for sites with higher differential speed limits (70/60 mph), and it was lowest (5.4 mph) for sites with higher uniform speed limits (65 and 70 mph). In sum, the difference in mean and 85th percentile truck and bus speeds in Indiana and Michigan were less than half of their differential speed limits. Higher differential speed limits were associated with higher variability in bus- and truck mean and 85th percentile speeds.

Garber et al. (2005) examined operational impacts of different speed limit policies on 17 rural interstate highways from 1991 to 2000. They found that regardless of speed limit policy (USL or DSL), measures including mean speed, 85th percentile speed, median speed, and crash rates increased over the 10-year period. The results suggested that changes in observed speeds were largely unaffected by speed limit policies.

Johnson and Pawar (2005) analyzed speed data collected on Arkansas and Illinois rural interstate highways with 70/65 and 65/55 mph speed limits, respectively. Arkansas with higher differential speed limit (70/65 mph) had speed variances smaller than Illinois with lower differential speed limit (65/55 mph). Analysis of speed data showed that Arkansas with higher speed limits had mean speeds, 85th percentile speeds, and compliance rates larger than Illinois with lower speed limits (except for Illinois with a 1 mph smaller 85th percentile car speed). Results are shown in Table 2-5.

Johnson and Murray (2010) compared the effect of different speed limit policies on vehicle speeds across the US. They collected speed data in 19 rural interstate locations, including

Oregon, with different speed configurations such as USL and DSL. They found that on average, states with 75 mph truck speed limits had only 6.3 mph higher mean truck speed than states with 55 mph truck speed limits. Similarly, on average, states with 75 mph truck speed limits had only 85th percentile truck speed of 1 mph higher than states with 70 mph truck speed limits. Results showed that there is differential between car and truck speed exists even for states with uniform speed limits, regardless of speed limit policy (DSL or USL). These results are shown in Figure 2-5.

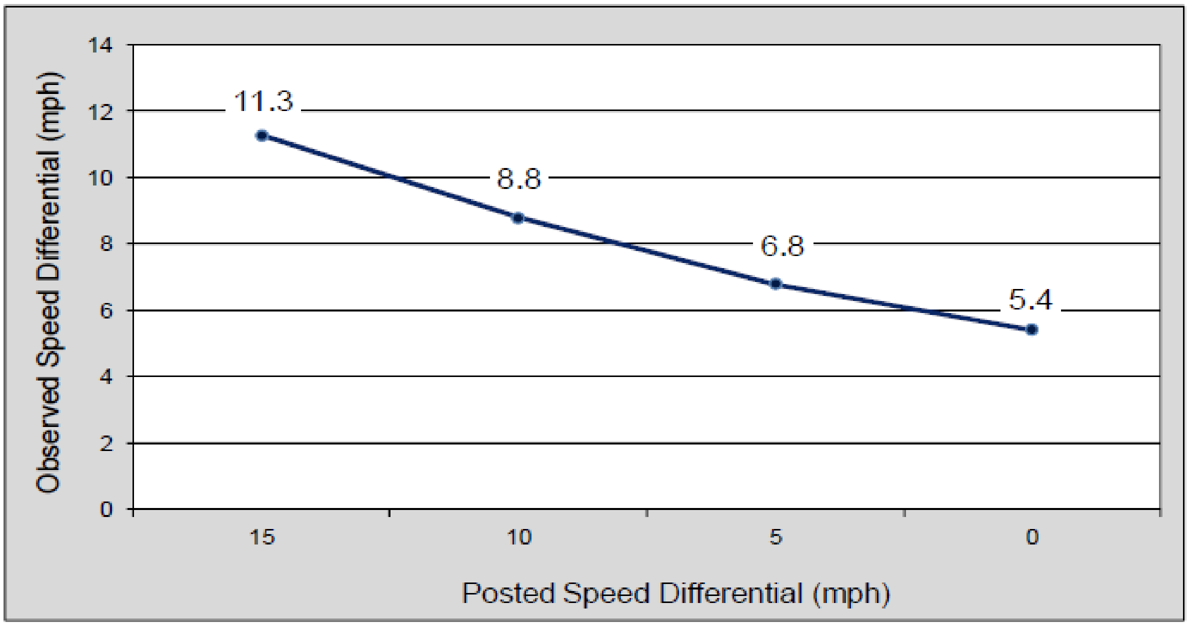


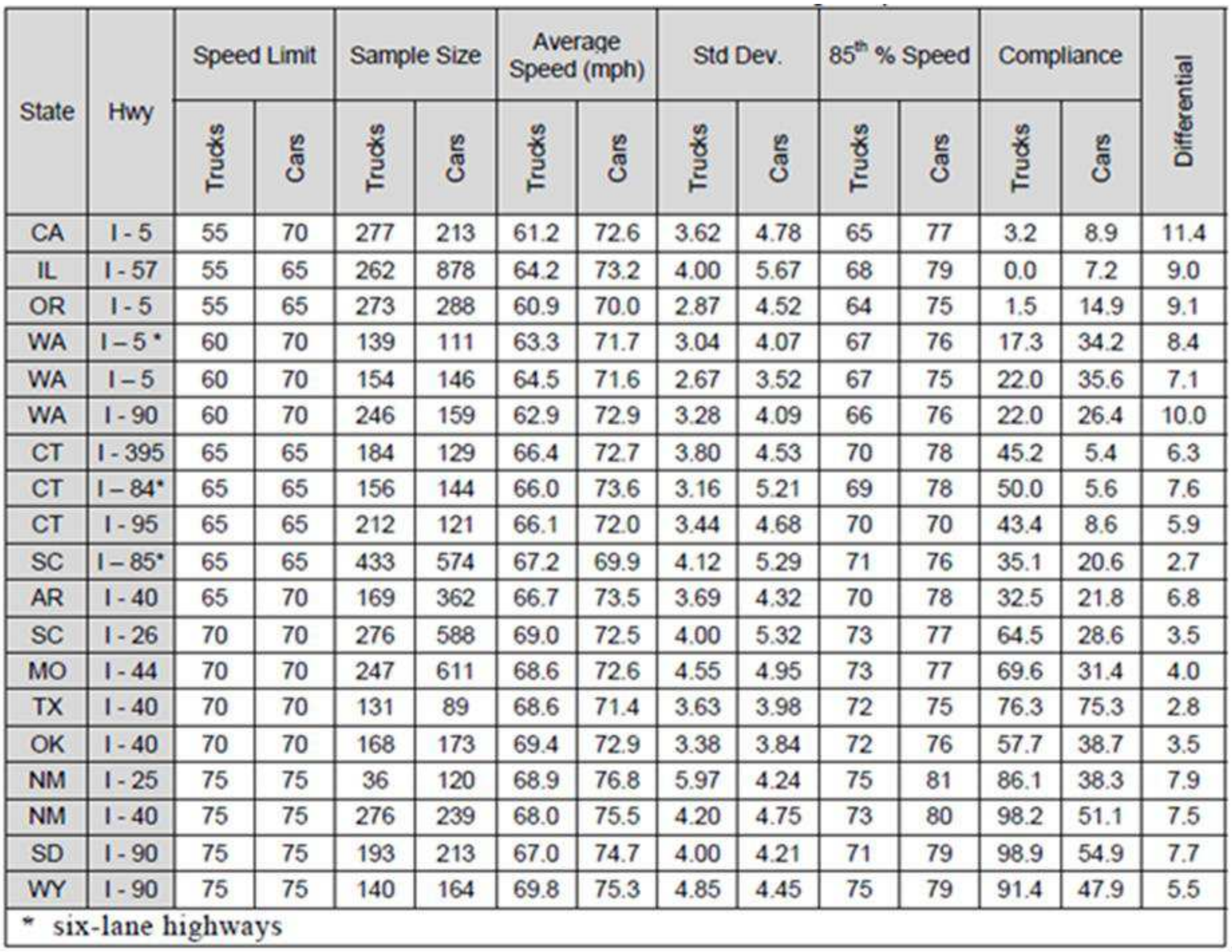
Figure 2-5: Observed Speed Differentials for Different Posted Speed Differentials, (Johnson and Murray 2010)

Table 2-5: The Effect of Differential Speed Limits on Observed Vehicle Speed Measures (Study Results)

No	**States**	**Policy**	**Before (mph)**	**After (mph)**	**The 85th Percentile Speed Change (mph)**	**Mean Speed Change (mph)**	**Compliance Rate Change**	**Speed Variance (mph)**
1	West Texas	USL to DSL$_{\text{(Cars)}}$	75	75/80		+6	-9% (>SL)	
		USL to DSL$_{\text{(Trucks)}}$	75	75/80		+3	-9% (>SL)	
2	Michigan	DSL$_{\text{(Car/Truck)}}$**	<65	70/60	< +5	< +5		6.9
	Indiana	DSL$_{\text{(Car/Truck)}}$**	<65	70/65	< +2.5	< +2.5		6.2
3	Idaho	USL to DSL$_{\text{(Trucks)}}$	75	75/65	-4.5	- 2.1	+10% (> SL)	
		USL to DSL$_{\text{(Cars)}}$	75	75/65		+1.1		
4	Montana	USL to DSL	65	70/60	+3.2	+1.6		+1.3
5	Arkansas vs. Illinois	DSL**$_{\text{(Trucks)}}$	65/55	70/65	+2	+2.5	32.5%	-0.3
		DSL**$_{\text{(Cars)}}$	65/55	70/65	-1	+0.3	14.5%	-1.3

*-Standard deviation in travel speeds; **- Comparing speed limits (instead of raising); (SL)-Speed Limit
1- (Retting and Cheung, 2008); 2- (Savolainen et al., 2014); 3- (Dixon et al., 2012); 4- (Gates et al., 2016);
5- (Johnson and Pawar, 2005).

Table 2-6: State Vehicle Speed Measures with Different Speed Limit Policy, (Johnson and Murray 2010)



State	Hwy	Speed Limit		Sample Size		Average Speed (mph)		Std Dev.		85th % Speed		Compliance		Differential
		Trucks	Cars	Trucks	Cars	Trucks	Cars	Trucks	Cars	Trucks	Cars	Trucks	Cars	
CA	I - 5	55	70	277	213	61.2	72.6	3.62	4.78	65	77	3.2	8.9	11.4
IL	I - 57	55	65	262	878	64.2	73.2	4.00	5.67	68	79	0.0	7.2	9.0
OR	I - 5	55	65	273	288	60.9	70.0	2.87	4.52	64	75	1.5	14.9	9.1
WA	I – 5 *	60	70	139	111	63.3	71.7	3.04	4.07	67	76	17.3	34.2	8.4
WA	I – 5	60	70	154	146	64.5	71.6	2.67	3.52	67	75	22.0	35.6	7.1
WA	I - 90	60	70	246	159	62.9	72.9	3.28	4.09	66	76	22.0	26.4	10.0
CT	I - 395	65	65	184	129	66.4	72.7	3.80	4.53	70	78	45.2	5.4	6.3
CT	I – 84*	65	65	156	144	66.0	73.6	3.16	5.21	69	78	50.0	5.6	7.6
CT	I - 95	65	65	212	121	66.1	72.0	3.44	4.68	70	70	43.4	8.6	5.9
SC	I – 85*	65	65	433	574	67.2	69.9	4.12	5.29	71	76	35.1	20.6	2.7
AR	I - 40	65	70	169	362	66.7	73.5	3.69	4.32	70	78	32.5	21.8	6.8
SC	I - 26	70	70	276	588	69.0	72.5	4.00	5.32	73	77	64.5	28.6	3.5
MO	I - 44	70	70	247	611	68.6	72.6	4.55	4.95	73	77	69.6	31.4	4.0
TX	I - 40	70	70	131	89	68.6	71.4	3.63	3.98	72	75	76.3	75.3	2.8
OK	I - 40	70	70	168	173	69.4	72.9	3.38	3.84	72	76	57.7	38.7	3.5
NM	I - 25	75	75	36	120	68.9	76.8	5.97	4.24	75	81	86.1	38.3	7.9
NM	I - 40	75	75	276	239	68.0	75.5	4.20	4.75	73	80	98.2	51.1	7.5
SD	I - 90	75	75	193	213	67.0	74.7	4.00	4.21	71	79	98.9	54.9	7.7
WY	I - 90	75	75	140	164	69.8	75.3	4.85	4.45	75	79	91.4	47.9	5.5

* six-lane highways

2.5.2 Impacts on Crash Frequency and Severity

The prior report did not find sufficient evidence to make a definitive conclusion about the effect of differential speed limits on safety. In the review of the literature published since the report, there is some limited evidence of improved safety on rural interstates due to differential speed limits. While most recent studies suggest that fewer truck- and bus- related fatalities are expected under differential speed limits than uniform speed limits along rural interstates, a few studies have also indicated that there is no significant difference or suggest an increase in crash frequency.

Davis et al. (2015) studied traffic fatalities on rural interstate highways from 1999 to 2011. They found that states with differential speed limits experienced 3.3% lower total fatal crashes and 24.6% lower truck- and bus-involved fatal crashes than states with uniform speed limits (Davis et al. 2015). Savolainen et al. (2014) found that on rural interstates, states with uniform speed limits had 20.5% higher truck- and bus-involved fatalities than states with differential speed limits. On urban interstates, total fatality rates were not significantly different between states with uniform speed limits and differential truck and bus speed limits.

In Michigan, urban freeways with USL (55 mph) had a 49% higher total crash rate, 97% higher injury rate, and 45% higher fatality rate than segments with DSL (70/60 mph) (Savolainen et al. 2014). Additional analysis showed that lower crash rates on freeways at 70 mph was reflective of freeways with higher design speeds and illustrated the importance of segment-specific geometric and traffic characteristics when speed limit increases are considered (Savolainen et al. 2014). After changing speed limits from a USL (75 mph) to a DSL (75/65 mph) on rural Idaho interstates, crash rates for all-vehicle and truck-involved crashes declined from 1998 to 2011 by 26% and 38%, respectively. A crash prediction model (SPF) showed that on average, truck-involved crashes decreased by 8.6%, with a standard deviation of 5.06% (Dixon et al. 2012). Differential speed limits and truck lane restriction policies were implemented on a Louisiana freeway. Results showed that total and truck-involved crashes decreased by 13% and 79%, respectively (Ishak et al. 2008; Korkut et al. 2010).

Garber et al. (2005) concluded that correlation between crash rates and type of speed limit was not clear. In Idaho, both an increase in the USL with an increase in mean speed and 85th percentile speed, and a change from USL to DSL did not significantly change crash rates, but significantly increased crash frequency in all types of crashes, except for truck-involved rear-end crashes. In Virginia, a change from DSL to USL with a significant increase in the compliance rate significantly increased total truck-involved crash rates and crash frequency in three of the five crash types. Gates et al. (2016) found that a change from a DSL (70/60 mph) to a USL (65 mph) on two-lane two-way rural highways that occurred along 55 miles in eastern Montana in April 2013 did not change non-animal related crashes significantly (Gates et al. 2016).

Traffic simulation models showed that differential speed limits (DSL) caused lower car-car overtaking but higher car-truck overtaking than uniform speed limits (USL). DSL and percentage of trucks slightly increased time to collision measures in the simulation models (TTC) (Ghods and Saccomanno 2016). Johnson and Pawar (2005) used simulation models to determine the number of interactions occurring among vehicles. They found that for an interstate differential speed limit of 65/55 mph, the number of interactions for trucks traveling at the speed limit (55 mph) would be four times greater than for trucks travelling at mean traffic speed.

Table 2-7: The Effect of Changing Speed Limit Policies on Crash Frequency and Severity (Study Results)

Study			Posted Speed Limits (mph)		Changes In Total Crashes		
Reference	**period**	**Scope**	**From**	**To**	**Fatal Crashes**	**Truck-Related Fatal Crashes**	**Frequency**
Davis et al.	1999-2011	US	USL*	DSL*	-3.3%	-24.6%	
Savolainen et al.	2004-2012	Michigan (Urban)	USL (55)	DSL (70/60)	-45% **		
			DSL* (65-70/60)	USL* (70)			Decreased
	1999-2011	US	USL*	DSL*		-20.5%	
Dixon et al.	1998-2011	Idaho	USL (75)	DSL (75/65)	-26%	-38%	
Korkut et al.	2004-2006	Louisiana	USL (60)	DSL (60/55)	-13%	-79%	
Gates et al.	2005-2014	Montana	DSL (70/60)	USL (65)			Non-SIG
Garber et al.	1991-2000	Idaho	USL	DSL			Increased
		Virginia	DSL	USL	Non-SIG**		Increased

* Comparing Speed Limits (instead of change from/to), ** Crash rate (instead of frequency)

2.6 OTHER FACTORS INFLUENCING CRASH FREQUENCY AND SEVERITY

Studies have found that other traffic parameters such as density, volume, and geometric features such as number of lanes, shoulder width and median type also play a role in the choice of speed, and thereby influence crash frequency and severity.

Kononov et al. found that traffic density (d) multiplied by speed squared (s^2) can be used as an explanatory variable ($FCPI=ds^2$) reflecting the probability of a crash. Their findings showed that flow crash potential indicator (FCPI) has a critical threshold ($FCPI_{cr}$), which if exceeded results in a rapidly increasing crash rate. The relationship between FCPI and crash rate is shown in Figure 2-6. Results of this study suggest that traffic volume should be taken into account when the effect of speed on road safety is evaluated (Kononov et al. 2012).

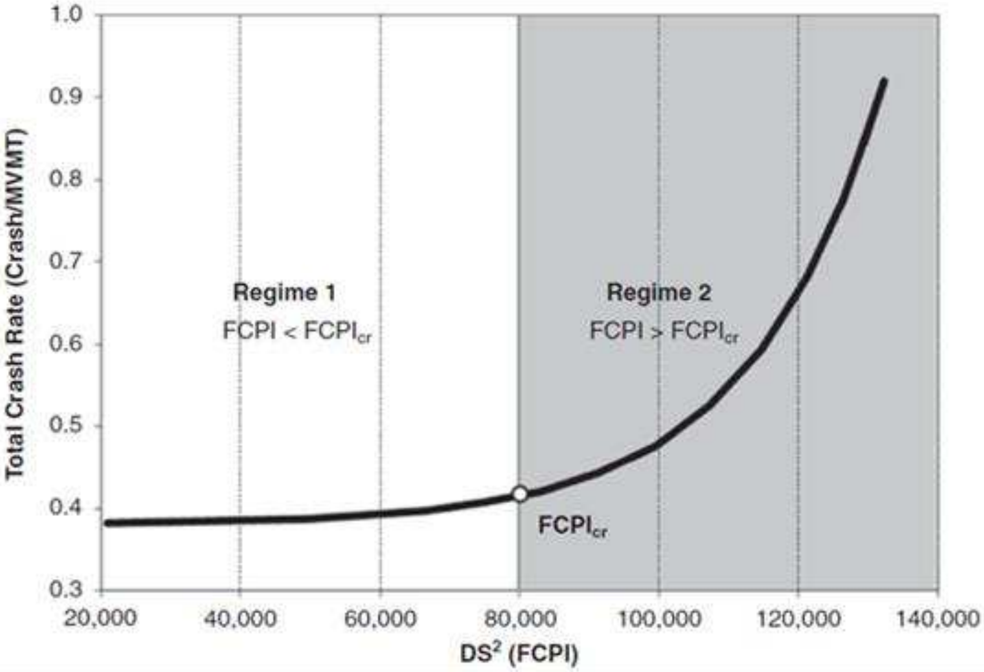


Figure 2-6: The Relationship between FCPI and Total Crash Rate per Million VMT

Other studies confirmed that traffic volume should be considered in the design of speed limits, even if 85th percentile speed under free-flow conditions allows an increase in the speed limit (Kononov et al. 2012; Russo et al. 2015; Christoforou et al. 2012; Ghods and Saccomanno 2016). Christoforou et al. found that traffic speed and volume were significant factors for predicting crash type and influencing injury severity level. Lower traffic volumes and higher speeds above certain traffic volume thresholds were associated with higher probability of severe accidents. Rear-end crashes were more likely to occur under low traffic volume and average speed, but sideswipe crashes were more likely to occur under high traffic volume on non-flat segments. Also, multi-vehicle crashes, other than rear-end crashes, were more likely to occur at high speeds, during daylight conditions, and on flat road segments, while single-vehicle crashes were more likely to occur on straight and flat segments. The lighting and road surface conditions were other significant factors affecting the injury severity level (Christoforou et al. 2012).

Mannering (2007) found that the effects of a wide variety of factors influencing driver's speed choice vary by speed limit. These factors include socioeconomic variables (age, number of children, gender and income), age when first licensed, and driver perceptions (pavement condition, vehicle prestige, etc.). Williams et al. (2006) found that speeders (drivers who drove 15 mph above the posted speed limits) were younger, more likely to drive newer vehicles and had more speeding violations or other traffic violations on their records. Islam et al. (2014) found that interaction terms between speed limits and road geometry such as number of lanes, shoulder width, and median type should be included in estimating crash prediction models (SPFs).

These findings suggest that traffic parameters and geometric factors also influence the choice of speed and thus should be considered in speed limit policy.

2.7 IMPACT OF TRUCK EQUIPMENT ON SAFETY

A few studies have looked at the impacts of safety equipment such as speed limiters and lane departure warning systems, forward collision warning systems, and roll stability systems on truck crashes (Orban et al. 2006, Bishop et al. 2008, Saccomano et al. 2009, Houser et al. 2009, Hanowski et al. 2012, Murray et al. 2009a, Murray et al. 2009b). These equipment have been found to have a positive impact on safety and reduce different types of truck crashes. Table 2-8 shows the key findings from these studies.

Speed limiters also known as speed governors are devices that interact with a truck engine to only permit the attainment of a pre-programmed maximum speed (Bishop et al., 2008). They are in use in Europe and Australia. Currently all new model trucks in the US are equipped with speed limiters. The advantages of using this equipment are proven safety benefits (reduction in crash rate, severity and speed variability), reduction in fuel use and tire wear (Bishop et al. 2008). Use of speed-limiting devices vary by industry segment (many long haul fleets will use the technology while owner-operators will be less likely). At higher posted limits this may result in increased speed variability whether or not DSL polices are in effect (Johnson and Pawar (2005). However, there are some concerns regarding their adoption including different maximum programmed speeds in US and Canada, loss of independence associated with driving at a set speed limit, loss of ability to accelerate in risky situations and improvements in fuel efficiency related to speed limiters and associated negative impacts on transportation funding (Bishop et al. 2008). Simulation studies that evaluated the impacts of speed limiters found they increased safety during uncongested flow regime and reduced in safety during congestion (Saccomano et al. 2009), and lowered crash rates (Bishop et al. 2008, Hanowski et al. 2012).

Lane departure warning systems consist of a main unit and a video camera, that is mounted on the windshield and records data on the roadway (Houser et al. 2009). The video images are processed to estimate the vehicle's state and warn drivers when a speed threshold is exceeded. Unlike speed limiters, these systems do not take any automatic action to avoid lane departure, instead they rely on the driver to perform the necessary action (Houser et al. 2009). Most studies found that LDWS reduce single vehicle roadway departure collisions and rollover crashes, same-direction lane departure sideswipe crashes and opposite-direction lane departure sideswipe and head-on collisions (Houser et al. 2009), and reduced conflicts on straight roads and curves (Orban et al. 2006). A survey conducted to understand driver perceptions regarding LWDS revealed that while the system helped them in maintaining their lane and was easy to use and understand, they were confused by multiple warnings provided by the system and were unable to distinguish lane departure warnings from other warnings (Orban et al. 2006).

Forward collision warning systems (FWCS) provide audible and/or visual warnings about vehicles and objects that come within a specified distance in front of a vehicle equipped with such a system (Murray et al. 2009a). These systems use Doppler based radar to determine the distance, difference in relative speed and angle between the truck and the object in front of it, and deliver warnings if necessary (Murray et al. 2009a). FWCS can also be integrated with adaptive cruise control (ACC) systems to reduce rear-end collisions, however they cannot automatically change the truck's trajectory or speed. Murray et al. studied the costs and benefits of forward collision warning systems and found reductions in rear-end crashes and expected positive returns on investment for carriers that use FWCS, who are also likely to be involved in a rear-end crash (Murray et al. 2009a).

Stability control systems incorporate sensors that monitor vehicle dynamics and determine a vehicle's stability based on its mass and velocity. Both roll stability and electronic stability systems can reduce the vehicle's throttle and apply the brakes to either reduce roll instability or both roll and yaw instability. Murray et al. also studied the impacts of roll stability control systems that are designed to reduce large truck roll-over crashes using a cost-benefit analysis and found reductions in combination vehicle rollover crashes (Murray et al. 2009b). The authors also state that small carriers may not break-even during the first five years post RSC deployment, however this equation may change, if the number of rollover crashes and/or their severity increases (Murray et al. 2009b).

Table 2-8: The Impact of Truck Equipment on Safety (Study Results)

Reference	Device	Type of Study	Key Findings
Saccomano et al. 2009	Speed Limiter	Simulation	Increases safety in the uncongested region of traffic flow As volumes and percentage of trucks increases, safety gains are less pronounced When volume approaches capacity, reduced safety is observed When compliance increases, small increase in safety is observed
Bishop et al. 2008	Speed Limiter	Survey	Speed limiters help in reducing top speed of the vehicle to improve safety and fuel economy Some respondents reported tampering with the speed limiters (22%-27%)
Hanowski et al. 2012	Speed Limiter	Field Test	Trucks equipped with speed limiters had significantly lower crash rate (50%) Cost of technology is negligible and not cost-prohibitive
Orban et al. 2006	Lane Departure Warning Systems	Field Test	Reduce driving conflicts on straight roads (31%), on curves (34%) Reduction in single vehicle roadway departure crashes (21%-23%) Reduction in rollover crashes (17%-24%)
Houser et al. 2009	Lane Departure Warning Systems	Cost-Benefit Analysis	Significant safety benefits from reduction is single vehicle roadway departure collisions and rollover crashes Positive return on investment
Murray et al. 2009	Forward Collision Warning Systems	Cost-Benefit Analysis	Between 8,597 and 18,013 rear-end crashes are likely to be prevented through the use of FWCS Positive return on investment is likely for carriers that use FWCS, that are also likely to be involved in a rear-end crash
Murray et al. 2009	Roll Stability Systems	Cost-Benefit Analysis	Between 1,422 and 2,037 combination vehicle rollover crashes are likely to be reduced in curves Net benefits are likely through the use of RSC

2.8 VEHICLE SPEEDS AND CRASHES IN WORK ZONES

Many studies have examined the effectiveness of different strategies and equipment in reducing crashes and severity of crashes in work zones. Our review focused on interstates. A summary of the literature is below.

Benekohal et al. found that automated speed photo-radar enforcement (SPE) significantly decreased mean vehicle speed and the percentage of vehicles exceeding the speed limit (55 mph) for both travel lanes in two work zones in Illinois (Benekohal et al. 2009). Bai et al. found that locating a portable changeable message sign (PCMS) 575 feet from the Road Work Ahead (RWA) sign upstream of a work zone resulted in the smallest speed variability between cars and trucks (Bai et al. 2015).

Edara et al. found that the deployment of advisory variable speed limit (VASL) in uncongested work zones of urban areas resulted in an average reduction of 2.2 mph in vehicle speed, and an increase in the standard deviation of vehicle speed by 4.4 mph, due to the advisory nature of VASL. The compliance rate with VASL was about eight times greater than without VASL, but this increase was not significant. For congested sites in urban work zones, VASL was effective in slowing vehicle speed approaching work zones gradually, preventing sudden reduction in vehicle speed within work zones. In two rural work zones, a static VASL sign reduced mean speed, speed variance, and 85th percentile speed downstream from the VASL sign, but these reductions were not significant except for speed variance in one site (Edara et al. 2008).

Vehicle speeds with a truck-mounted radar speed sign (RSS) display turned on were compared with a RSS display turned off in work zones on high-speed (55 and 65 mph) roadways in Oregon. The findings revealed that 85th percentile speed from the location of the RWA sign to the active work area decreased by 1-8 mph (1-15 %). The compliance rate in the work zone increased by 12%. The mean speed slightly increased in the work zone but decreased from the RWA sign to the work zone. The difference between speeds of adjacent vehicles passing through the work zone decreased by 2 mph. Distances between adjacent vehicles passing through the work zone also decreased. Overall, the effect of truck-mounted RSS on reducing vehicle speeds in work zones was found promising (Gambatese and Jafarnejad 2015).

Li et al. found that drivers aged between 35 and 44 accounted for the majority of fatal crashes (34%) in Kansas highway work zones. Most crashes occurred during daylight hours (10:00 am – 4:00 pm). Truck-related crashes most often occurred when weather conditions were clear and road surface was dry. Rear-end crashes were the dominant type of crash for all injury levels. Highways with 65 mph speed limits comprised most fatal crashes. More than 50% of fatal crashes occurred on straight and flat highway work zones. Light conditions, vehicle maneuvers, crash type, number of vehicles, speed limit, area information and traffic control may affect crash severity in work zones (Li et al. 2011). Osman et al. found that daytime crashes, no control of access, higher speed limits and crashes on rural principal arterials were important factors contributing to higher severity level of truck-involved crashes in work zones in Minnesota (Osman et al. 2016).

3 CONCLUSIONS

Numerous studies have investigated the effects of raising speed limits and impacts of uniform versus differential speed limit policies on crash frequency and severity after the repeal of National Maximum Speed Law (NMSL) in 1995. The relationship of speed and safety is a complex relationship that continues to be the focus of research. This report updates a select number of topics that were included in the "Impacts and Issues Related to Proposed Changes in Oregon's Interstate Speed Limits" submitted to ODOT in 2004 (Monsere et al. 2004) including new topics on work zones and truck equipment.

In compiling this report, no original data analysis was conducted. The objective of the report was to prepare a summary of the impacts of raising speed limits documented in recently published literature. These findings can be considered by policymakers with other criteria. Based on the literature review, key findings are summarized below:

- Currently seven states employ differential speed limits for trucks on interstate facilities. The minimum speed differential is 5 mph and the maximum is 15 mph.
- The literature published since the last study supports the previous conclusion that an increase in speed limits will increase the mean and 85th percentile vehicle speeds. This increase is typically lower than the speed limit increase (implying that most vehicles are already traveling above the speed limit prior to the change). This finding is applicable for both cars and trucks.
- The prior report concluded that raising speed limits is associated with an increase in the number of crashes, fatalities and serious injuries. This literature published since the last study is consistent with this finding.
- The prior report did not find sufficient evidence to make a definitive conclusion about the effect of differential truck speed limits on safety. The subject remains challenging to study, partly because of the confounding effects of the two results of DSLs (increased speed differences of vehicles in the traffic stream and lower speeds for heavy vehicles). The recent literature and analysis suggest that an increase in differential speed limits increases the mean and 85th percentile speeds for both cars and trucks. With respect to safety, the findings of this report suggest that there is some limited evidence of improved safety, particularly along rural interstates, due to differential speed limits.
- Newer truck equipment such as speed limiters (governors), lane departure warning systems, forward collision warning systems, and stability control systems have the potential to decrease truck crashes and improve safety. The extent of industry adoption of these technologies in the fleet was not quantified and would be key in determining the possible safety effects of these technologies.
- For work zones, use of variable message signs and radar speed signs helped in reducing truck speeds through work zones and increasing compliance.

Not all impacts of the proposed changes to speed limits were studied in this update or in the prior report. Speed limit decisions ultimately involve trade-offs in safety, the efficiency of travel, and societal values. It is recommended that detailed engineering and safety analyses are conducted prior to any speed limit changes. Examination of mean and 85th percentile speeds, speed variability, crash history and roadway geometry, and traffic volumes may be warranted along roadways under consideration. Additionally, examination of economic, environmental, and health-related impacts should also be considered.

4 REFERENCES

Alemazkoor, N., and H. G. Hawkins. 2014. *Examining Impacts of Increasing Speed Limit on Speed Distribution: Case Study*. Submitted at Transportation Research Board 93rd Annual Meeting, Washington, D.C., 2014.

Abdullah, A., H. Yamanaka, and M. Rehan. 2011. Empirical analysis of gross vehicle weight and free flow speed and consideration on its relation with differential speed limit. *Accident Analysis and Prevention*, Volume 43, No. 3, 2011, pp. 1068–1073.

Aarts, L., and I. Van Schagen. 2006. Driving speed and the risk of road crashes : A review. *Accident Analysis & Prevention*, Volume 38, No. 2, 2006, pp. 215–224.

Bai, Y., Finger, K., & Li, Y. 2010. Analyzing motorists' responses to temporary signage in highway work zones. *Safety Science*. Vol. 48, No. 2, 2010, pp.215-221.

Bham, G. H., & Mohammadi, M. A. 2011. Evaluation of Work Zone Speed Limits: An Objective and Subjective Analysis of Work Zones in Missouri. Washington, DC: USDOT RITA. Publication: MATC-MST: 119.

Benekohal, R. F., Wang, M.-H., Chitturi, M. V., Hajbabaie, A., & Medina, J. C. 2009. Speed Photo–Radar Enforcement and Its Effects on Speed in Work Zones. *Transportation Research Record: Journal of the Transportation Research Board*. No. 2096, 2009, pp. 89-97.

Bai, Y., Yang, Y., & Li, Y. 2015. Determining the effective location of a portable changeable message sign on reducing the risk of truck-related crashes in work zones. *Accident Analysis & Prevention.* Vol. 83, pp. 197-202.

Christoforou, Z., S. Cohen, and M. G. Karlaftis. 2012. Integrating Real-Time Traffic Data in Road Safety Analysis. *Procedia - Social and Behavioral Sciences*, Volume 48, 2012, pp. 2454-2463.

Chen, Y., Qin, X., & Noyce, D. A. 2007. Evaluation of Strategies to Manage Speed in Highway Work Zones. Washington, DC: *Transportation Research Board 86th Annual Meeting*.

Donnell, E. T., B. Hamadeh, L. Li, and J. Wood. 2016. *70 mph Study*. Publication FHWA-PA-2016-009-PSU WO 13. The Pennsylvania Department of Transportation, 2016.

Davis, A., E. Hacker, P. T. Savolainen, and T. J. Gates. 2015. Longitudinal Analysis of Rural Interstate Fatalities in Relation to Speed Limit Policies. In *Transportation Research Record: Journal of the Transportation Research Board, No. 2514*, Transportation Research Board, Washington, D.C., 2015, pp. 21-31.

Davis, A., E. Hacker, P. T. Savolainen, and T. J. Gates. Longitudinal Analysis of Rural Interstate Fatalities in Relation to Speed Limit Policies. In *Transportation Research Record: Journal of the Transportation Research Board, No. 2514,* TRB, Transportation Research Board, Washington, D.C., 2015, pp. 21-31.

Dixon, M. P., A. Abdel-Rahim, and S. Elbassuoni. 2012. *Evaluation of the Impacts of Differential Speed Limits on Interstate Highways in Idaho*. Publication FHWA-ID-13-218. Idaho Transportation Department, 2012.

Donnell, E. T., S. C. Himes, K. M. Mahoney, R. J. Porter, and H. McGee. 2009. *Speed Concepts : Informational Guide*. Publication FHWA-SA-10-001. FHWA, U.S. Department of Transportation, Washington D.C., 2009.

Debnath, A. K., Blackman, R., & Haworth, N. 2015. A Comparison of Self-Nominated and Actual Speeds in Work Zones. *Transportation Research Part F: Traffic Psychology and Behaviour*. Vol. 35, 2015, pp 213-222.

Debnath, K. A., Blackman, R., & Haworth, N. 2015. Speeding through roadworks: understanding driver speed profiles and ways to reduce speeding. Australasian Road Safety Conference, 1st, 2015, Gold Coast, Queensland, Australia.

Elvik, R. 2005. Speed and Road Safety Synthesis of Evidence from Evaluation Studies. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1908,* Transportation Research Board of the National Academies, Washington, D.C., 2005, pp. 59–69.

Elvik, R. 2009. *The Power Model of the relationship between speed and road safety*. Institute of Transport Economics Norwegian Center for Transport Research, 2009.

Edara, P., Sprengeler, D., & Sun, C. 2008. Evaluation of Variable Advisory Speed Limit Systems for Work Zones. University of Missouri, Columbia. Publication: InTrans Project 06-277.

Friedman, L. S., D. Hedeker, and E. D. Richter. 2009. Long-term effects of repealing the national maximum speed limit in the United States. In *American Journal of Public Health,* Volume 99, 2009, pp. 1626–1631.

Farmer, C. M. 2016. *Relationship of Traffic Fatality Rates to Maximum State Speed Limits*. Insurance Institute for Highway Safety, 2016.

FMCSA. 2016. *Motor Carrier Safety Progress Report.* FMCSA, US Department of Transportation, 2016.

FMCSA Analysis Division. 2011. *Large Truck and Bus Crash Facts 2009*. Publication

FMCSA-RRA-11-025. FMCSA, U.S. Department of Transportation, Washington D.C., 2011.

FMCSA. 2013. *Large Truck and Bus Crash Facts 2011*. Publication FMCSA-RRA-13-049. FMCSA, U.S. Department of Transportation, Washington D.C., 2013.

Faisal, A. 2007. Differential Speed Limit Analysis and Regulations on Rural Expressways. Road & Transport Research: *A Journal of Australian and New Zealand Research and Practice*. Vol. 16, No. 4, 2007, pp. 16-25. Link to study

Fitzharris, M., Truong, J., Stephan, K., Healy, D., Rowe, G., Collins, S., & Newstead, S. 2011. The Victorian Intelligent Speed Assist And Heavy Vehicles Trial: Analysis Of Device Acceptability And Influence On Speed Choice. 22nd International Technical Conference on the Enhanced Safety of Vehicles (ESV). Publication: 11-0244.

Ghods, A. H., Saccomanno, F., & Guido, G. 2012. Effect of Car/Truck Differential Speed Limits on Two-Lane Highways Safety Operation using Microscopic Simulation. *Procedia - Social and Behavioral Sciences*, Vol. 53, 2012, pp. 833-840.

Green, C. 2015. *The Relevance of the Posted Minimum Speed Limit on Interstates: The Case Study of South Carolina*. Submitted for Presentation at the 2015 Annual Transportation Research Board Conference, Washington, D.C., 2015.

Goodwin, R. E., and U. Anderson. 2005. *Analysis of Texas Speed Limit Laws and Fatality Accident Rates*. Publication SWUTC/05/167320-1. Southwest Region University Transportation Center, 2005.

Garber, N. J., J. S. Miller, B. Yuan, and X. Sun. 2005. *Safety Effects of Differential Speed Limits on Rural Interstate Highways*. Publication FHWA-HRT-05-042. FHWA, 2005.

Gates, T. J., R. Hamzeie, J. J. Kay, S. Frazier, and J. Finkelman. 2016. *Safety and Operational Impacts of Differential Speed Limits on Two-Lane Rural Highways in Montana*. Publication FHWA/MT – 16-006/8224-001. Montana Department of Transportation, 2016.

Ghods, A. H., and F. F. Saccomanno. 2016. Safety and traffic implications of differential car and truck speed controls for two-lane highways. *Journal of Transportation Engineering*, Volume 42, No 11, 2016.

Grant W. Neeley and Lilliard E. Richardson, Jr. 2009. The Effect of State Regulations on Truck-Crash Fatalities. *American Journal of Public Health*: March 2009, Vol. 99, No. 3, pp. 408-415.

Governors Highway Safety Association. 2017. State Laws by Issue. *Speeding and Aggressive Driving*. http://www.ghsa.org/state-laws/issues/Speeding-and-Aggressive-Driving. Accessed Jan. 1, 2017.

Gambatese, J. A., & Jafarnejad, A. 2015. Evaluation of Radar Speed Display for Mobile Maintenance Operations. Oregon Dept. of Transportation, U.S. Dept. of Transportation. Publication: OR-RD-16-09.

Hu, W., and A. McCartt. 2014. *Raising the Speed Limit from 75 to 80 mph on Utah Rural Interstate: Effects on Vehicle Speeds*. Transportation Research Board 93rd Annual Meeting, 2014.

Haas, P. R., X. Zhu, N. S. Dhakar, G. Carrick, and S. Srinivasan. 2012. *An Analysis of Crashes, Injuries, and Speeds on Freeway Enhanced Penalty Zones*. Transportation Research Board 91st Annual Meeting, 2012.

Hanowski, R. J., G. Bergoffen, J. S. Hickman, F. Guo, D. Murray, R. Bishop, S. Johnson, and M. Camden. 2012. *Research on the Safety Impacts of Speed Limiter Device Installations on Commercial Motor Vehicles : Phase II*. Publication FMCSA-RRR-12-006. FMCSA, U.S. Department of Transportation, 2012.

Hickman, J. S., G. Bergoffen, D. C. Murray, W. Mcdonald, and R. Bishop. 2008. *Safety Impacts of Speed Limiter Device Installations on Commercial Trucks and Buses*. CTBSSP Synthesis 16. FMCSA, Transportation Research Board, Washington, D.C., 2008.

Houser, A., D. Murray, S. Shackelford, R. Kreeb, and T. Dunn. 2009. *Analysis of Benefits and Costs of Lane Departure Warning Systems for the Trucking Industry*. Publication FMCSA-RRT-09-022. FMCSA, U.S. Department of Transportation, 2009.

Hourdos, J. 2012. Portable, Non-Intrusive Advance Warning Devices for Work Zones with or without Flag Operators. Minnesota Department of Transportation. Publication: MN/RC 2012-26.

Islam, M., J. Ivan, N. Lownes, R. Ammar, and S. Rajasekaran. 2014. Developing Safety Performance Function for Freeways by Considering Interactions Between Speed Limit and Geometric Variables. In *Transportation Research Record: Journal of the Transportation Research Board, No. 2435*, Transportation Research Board of the National Academies, Washington, D.C., 2014, pp. 72-81.

Ishak, S., B. Wolshon, M. Korkut, Y. Qi, and X. Sun. 2008. *Evaluation of the Traffic Safety Benefits of a Lower Speed Limit and Restriction of Trucks to Use of Right Lane Only on I-10 Over the Atchafalaya Basin*. Publication FHWA/LA.08/435. Louisiana Transportation Research Center, 2008.

Johnson, S. L., & Pawar, N. 2005. *Cost/Benefit Evaluation of Large Truck-Automobile Speed Limit Differentials on Rural Interstate Highways*. US Department of Transportation, Publication: MBTC 2048.

Johnson, S., and D. Murray. 2010. *Empirical Analysis of Truck and Automobile Speeds on Rural Interstates : Impact of Posted Speed Limits*. Transportation Research Board 89th Annual Meeting, 2010.

Kockelman, K. 2006. *Safety Impacts and Other Implications of Raised Speed Limits on High-Speed Roads*. NCHRP Web-Only Document 90 (Project 17-23), 2006.

Kononov, J., C. Durso, D. Reeves, and B. Allery K. 2012. Relationship Between Traffic Density, Speed, and Safety and Its Implications for Setting Variable Speed Limits on Freeways. In *Transportation Research Record: Journal of the Transportation Research Board, No.* 2280, TRB, Transportation Research Board of the National Academies, Washington, D.C., 2012, pp. 1-9.

Korkut, M., S. Ishak, and B. Wolshon. 2010. Freeway Truck Lane Restriction and Differential Speed Limits Crash Analysis and Traffic Characteristics. *Transportation Research Record: Journal of the Transportation Research Board, No. 2194,* TRB, Transportation Research Board of the National Academies, Washington, D.C., 2010, pp. 11-20.

Li, Y., Bai, Y., Schrock, S. D., & Mulinazzi, T. E. 2011. Modeling Truck Speed in the Upstream of One-lane Two-way Highway Work Zones: Implications on Reducing Truck-Related Crashes in Work Zones. Research and Innovative Technology Administration. Publication: 25-1121-0001-362.

Monsere, C. M., C. Newgard, J. Dill, A. Rufolo, E. Wemple, R. L. Bertini, and C. Milliken. 2004. *Impacts and Issues Related to Proposed Changes in Oregon's Interstate Speed Limits*. Oregon Department of Transportation.

Malyshkina, N. V., and F. Mannering. 2008. *Effect of Increases in Speed Limits on Severities of Injuries in Accidents*. In *Transportation Research Record: Journal of the Transportation Research Board, No. 2083*, Transportation Research Board of the National Academies, Washington, D.C., 2008, pp. 122-127.

Mannering, F. 2007. *The effects of interstate speed limits on driving speeds : Some new evidence*. Presented at Transportation Research Board 86th Annual Meeting, Washington, D.C. 2007.

Muchuruza, V., and R. Mussa. 2005. Operational and Safety Evaluation of Freeways with Posted Minimum Speed Limit. In *Journal of the Transportation Research Forum,* Volume 44, No. 3, 2005, pp. 5-17.

Murray, D., S. Shackelford, and A. Houser. 2009. *Analysis of Benefits and Costs of Forward Collision Warning Systems for the Trucking Industry*. Publication FMCSA-RRT-09-0212009. FMCSA, U.S. Department of Transportation, 2009.

Murray, D., S. Shackelford, and A. Houser. 2009. *Analysis of Benefits and Costs of Roll Stability*

Control Systems for the Trucking Industry. Publication FMCSA-RRT-09-020. FMCSA, U.S. Department of Transportation, 2009.

McAvoy, S. D., Duffy, S., & Whiting II, H. S. 2011. Simulator Study of Primary and Precipitating Factors in Work Zone Crashes. Transportation Research Record: Journal of the Transportation Research Board. No. 2258, Transportation Research Board of the National Academies. Washington, D.C., 2011, pp. 32–39.

NHTSA. 2014. *Traffic Safety Facts: 2012 Data*. Publication DOT HS 812 016. NHTSA, U.S. Department of Transportation, 2014.

Orban, J., J. Hadden, G. Stark, and V. Brown. 2006. *Evaluation of the Mack Intelligent Vehicle Initiative Field Operational Test*. Publication FMCSA-06-016. FMCSA, U.S. Department of Transportation, 2006.

OECD. 2006. *Speed Management*. European Conference of Ministers of Transport, 2006.

Oregon Truck Safety. 2017. Inspection Info. *Truck Safety Inspection Stats for 2013*. http://www.oregon.gov/ODOT/MCT/pp./SAFETY.aspx#Inspection. Accessed February 24, 2017.

Osman, M., Paleti, R., Mishra, S., & Golias, M. M. 2016. Analysis of injury severity of large truck crashes in work zones. Accident Analysis & Prevention, Vol. 97, 2016, pp. 261-273.

Porter, R. J., & Mason Jr, J. M. 2008. Modeling Speed Behavior of Passenger Cars and Trucks in Freeway Construction Work Zones: Implications on Work Zone Design and Traffic Control Decision Processes. Journal of Transportation Engineering. Vol. 134, No. 11, 2008, pp. 450-458.

Rawson, C. T. 2015. *Procedures for Establishing Speed Zones*. Texas Department of Transportation, 2015.

Retting, R., & Cheung, I. 2008. Traffic speeds associated with implementation of 80 mph speed limits on West Texas rural interstates. *Journal of Safety Research,* Vol. 33, No. 5, 2008, pp. 529-534.

Retting , R. A., & Teoh, E. R. 2008. Traffic Speeds on Interstates and Freeways 10 Years After Repeal of National Maximum Speed Limit. *Traffic Injury Prevention,* Vol. 9, No. 2, 2008, pp. 119-124.

Russo, B. J., Savolainen, P. T., Gates, T. J., Kay, J. J., & Frazier, S. 2016. Driver Speed Selection on High-Speed Two-Lane Highways: Comparing Speed Profiles between Uniform and Differential Speed Limits. *Traffic Injury Prevention,* 2016, pp. 1-7.

Russo, B. J., Rista, E., Savolainen, P. T., Gates, T. J., & Frazier, S. 2015. Vehicle Speed Characteristics in States with Uniform and Differential Speed Limit Policies. Transportation Research Record: Journal of the Transportation Research Board, Vol. 2492, 2015, pp. 1 –9.

Savolainen, P., T. Gates, E. Hacker, A. Davis, S. Frazier, B. Russo, E. Rista. 2014. *Evaluating the Impacts of Speed Limit Policy Alternatives*. Publication RC-1609. Michigan Department of Transportation, 2014.

Souleyrette, R. R., T. B. Stout, and A. 2009. Carriquiry. *Evaluation of Iowa's 70 mph Speed - 2.5 Year Update*. Publication CTRE Project 06-247. Iowa Highway Research Board, Iowa Department of Transportation, 2009.

Savolainen, P., T. Gates, E. Hacker, A. Davis, S. Frazier, B. Russo, E. Rista. 2014. *Evaluating the Impacts of Speed Limit Policy Alternatives*. Publication RC-1609. Michigan Department of Transportation, 2014.

Saccomanno, F. F., D. Duong, F. Cunto, B. Hellinga, C. Philp, and P. Thiffault. 2009. Safety Implications of Mandated Truck Speed Limiters on Freeways. In *Transportation Research Record: Journal of the Transportation Research Board, No. 2096*, TRB, Transportation Research Board of the National Academies, Washington D.C., 2009, pp. 65–75.

Vernon, D. D., L. J. Cook, K. J. Peterson, and J. Michael Dean. 2004. Effect of repeal of the national maximum speed limit law on occurrence of crashes, injury crashes, and fatal crashes on Utah highways. *Accident Analysis & Prevention*. Volume 36, 2004, pp. 223-229.

Williams, A. F., Kyrychenko, S. Y., & Richard , R. A. 2006. Characteristics of speeders. *Journal of Safety Research*, Vol. 37, No. 3, 2006, pp. 227–232.

Y Hou, P Edara, and C Sun. 2013. Speed Limit Effectiveness in Short-Term Rural Interstate Work Zones. In *The International Journal of Transportation Research,* Volume 5, No. 1, 2013, pp. 8-14.

APPENDIX

A. Recent Changes to State Speed Limit Policies, (Gates et al. 2016)

State	Type of Roadway	Prior Limit	New Limit	Effective Date
Ohio	Ohio Turnpike	65	70	April 2011
Louisiana	Select Rural Freeways	70	75	July 2011
Kansas	Rural Freeways	70	75	July 2011
Indiana	Tollway	55	70	February 2012
Arkansas	Select Rural Highway	55	60; 65	June 2012
Texas	Rural Freeways; Tollway	75; 80	80; 85	October 2012
Kentucky	Select US Highway	55	65	October 2012
Montana	Select Rural Highways	70c/60t	65c/65t	April 2013
Ohio	Select Rural Freeways	65	70	July 2013
North Carolina	Select Rural Freeways	65	70	September 2013
Utah	Select Rural Freeways	75	80	September 2013
Alaska	State Highways	55	65	November 2013
Georgia	Select Interstates	55	65	November 2013
Illinois	Tollway; Select Freeways	55; 65	70	January 2014
New Hampshire	Select Interstates	65	70	January 2014
South Carolina	Select State Highways	55	60	January 2014
Pennsylvania	Rural Freeways	65	70	January 2014
Maine	Select Interstates	55-65	60-70	May 2014
Wyoming	Select Interstates	75	80	July 2014
Idaho	Select Interstates	75	80	August 2014
South Dakota	Select Interstates	75	80	April 2015
Wisconsin	Rural Interstates, Select Fwys	65	70	June 2015
Maryland	Select Interstates	65	70	September 2015
Montana	Rural Interstates	75	80	October 2015
Nevada	Select Freeways	75	80	October 2015
Kentucky	Select Rural Highways	55	65	October 2015
Washington	Select Freeways	70c/60t	75c/60t	February 2016
Oregon	Select Rural Highways and Select Rural Freeways	55;65c/55t	65c/60t;70c/65t	March 2016