TRAFFIC OPERATIONS & SAFETY LABORATORY

IMPACT OF RAISING SPEED LIMITS ON TRAFFIC SAFETY - DRAFT LITERATURE REVIEW

BY

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INTRODUCTION

The primary purpose of speed limits is to enhance traffic safety (1). Speed limits achieve this objective in two ways. First, by establishing an upper speed bound, speed limits have a ceiling effect and therefore aim to reduce probability and severity of crashes. Second, speed limits reduce dispersion in driving speeds thereby reducing vehicular conflicts. Apart from these primary functions, speed limits help to improve traffic flow efficiency. Historically, speed limits have also been used as a means of energy conservation.

In spite of these benefits, setting the speed limit of a road to an arbitrary value may, and most likely will, have a deteriorative effect on traffic flow and safety, as will become obvious from the literature reviewed in the following sections. In other words, imposing a speed limit is effective only if its value is set within an appropriate range. The effectiveness wanes as this value increases or decreases outside this range. Moreover, this range differs from one roadway to another, depending on a multitude of factors. Traffic engineers therefore endeavor to determine the appropriate speed limit value for a given roadway.

Up until 1995, the federal government controlled (albeit indirectly) the maximum speed limit that could be set on any road in the United States. After November 1995, the federal government allowed all states to determine and implement their own speed limits. Many states raised their speed limits at that time. Currently, Wisconsin has a number of neighboring states who have increased the speed limit on their freeways and expressways to 70 mph (from 65 mph). The motivation for this literature survey is to review the historical results of incorporating this change.

First a brief history of the speed limit changes in the United States is discussed. Studies pertinent to these speed limit changes are then reviewed in a literature survey. Based on the literature reviewed, an attempt is made to identify traffic safety related issues pertaining to speed limit increase. Finally, recommendations and conclusions are discussed.

HISTORY OF SPEED LIMIT CHANGE IN THE UNITED STATES

National speed limits have been set in the United States twice (1). The first time was during World War II, when a speed limit of 35 mph was imposed. After the war, the statutory national speed limit was removed. Prior to 1973, many states had maximum speed limits of 70 or 75 mph. Then in 1973, as a result of the energy crisis at that time, the federal government passed the Emergency Highway Conservation Act. As a result of this act, the National Maximum Speed Limit (NMSL) was limited to 55 mph on interstates. According to Monsere et al (2), in the years following the 55 mph speed limit, the number of fatalities in the interstate system declined drastically, as a consequence of perhaps the 55 mph speed limit but also because of less travel. As the energy crisis disappeared, Congress was under increasing pressure to raise the speed limits. In 1984, a study was commissioned by the Congress to review the impact of the 55 mph speed limit. Although this study recommended retaining the 55 mph limit, the Congress passed the Surface Transportation and Uniform Relocation Act in April, 1987. This Act permitted states to raise interstate speed limits to 65 mph, but only on rural sections. Finally, in November 1995, the federal government passed the National Highway System Designation Act and returned all speed limit authorities to the states. Post November 1995, several states raised their speed limits. Currently all states have a maximum interstate speed limit between 65 mph and 75 mph. APPENDIX I (3) shows the current speed limits for various types of roads in the 50 US states and District of Columbia. Note that the current maximum speed limit in rural and urban interstates as well as other limited access roads in Wisconsin is 65 mph.

SPEED LIMIT CHANGE LITERATURE REVIEW

A review of some of the existing literature regarding speed limit change is discussed below. Each paper is discussed in a separate subsection and at the end of each subsection, there is a bulleted summary highlighting the key elements of the research.

Solomon

In 1964, Solomon (4) investigated the relationship between speed, characteristics of drivers and vehicles, and accidents. This study was based on approximately 600 miles of 2 and 4 lane rural highways. A variety of data was collected through the review of 10,000 crash records. In addition, data such as driver age, gender, vehicle horsepower etc. was collected through driver interviews. Data was collected over a 2 year time period and included day, night and weekend samples. Of major relevance to our literature review is the U-shaped curve developed by Solomon that shows the accident involvement rate as a function of speed (Figure 1).

In Figure 1, the accident involvement rate is the number of vehicles involved in accidents per 100 million vehicle miles of travel. Travel speed is the reported speed of the driver at the time of accident. Figure 1 shows that involvement rate was highest for very low speed drivers. It reached a low point at about 65 mph and beyond that, it increased again. Solomon (4) also calculated the involvement rate vs the difference in mean speed of the section and reported travel speed of the crash involved driver. The curve for this relation is illustrated in
Figure 2.

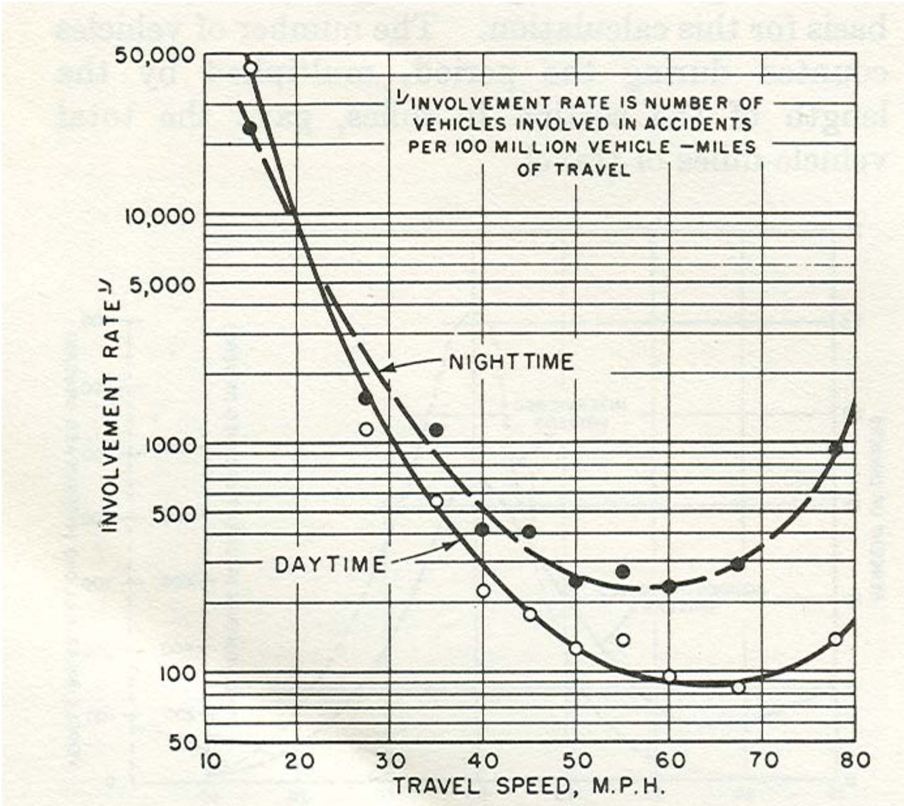

Figure 1 Involvement Rate by Travel Speed- Day and Night (4)

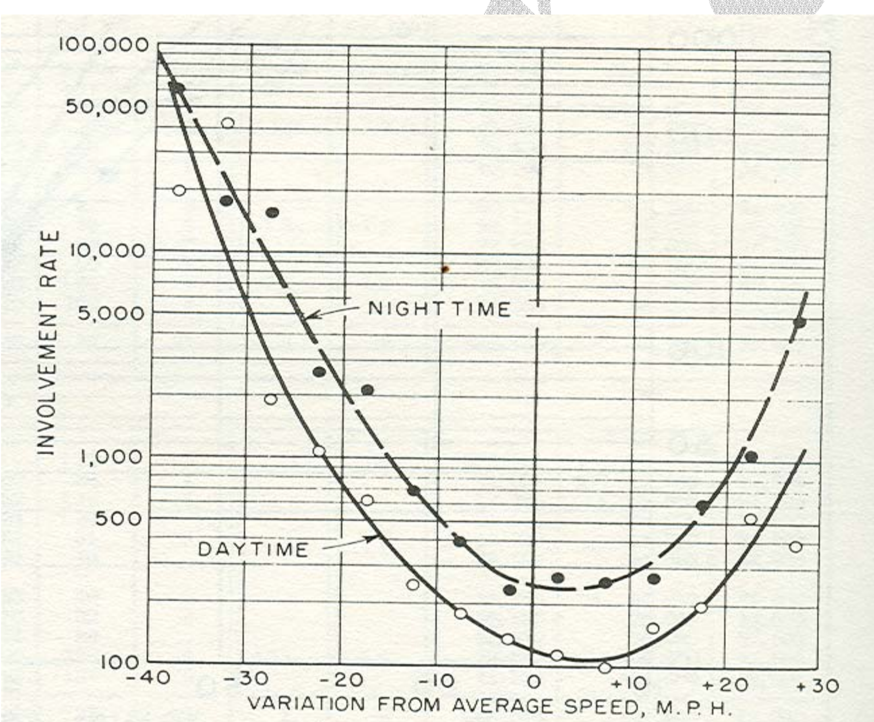

Figure 2 Involvement Rate by Variation from Average Speed, Day and Night

As seen in
Figure 2, the crash involvement rate is minimal near the average speed of traffic. This clearly indicates that that as speed variations increase, the involvement rate goes up.

Another finding from Solomon's study was that the accident severity increased with increased speed on rural roads (4). From analyzing over 10,000 crash records, Solomon found that the severity of crashes (in terms of persons injured as well as property damage value) increased rapidly for speeds over 60 mph. The probability of a fatal injury rose sharply for speeds over 70 mph.

Monsere et al (2) discussed a couple of criticisms for Solomon's (4) results. First, the average speed was taken at only select sections of the highway, but the crashes occurred all over. As a result, the average speed may not have been depicted accurately. Second, the speeds of the crash involved drivers were taken from police reports which again, may not have been that accurate. Moreover, although roadways were selected so as to minimize driveways, Solomon's data also included turning vehicles, which contribute to unusually high crash involvement rates for slow moving vehicles. Nevertheless Solomon's (4) results clearly underscore the need to reduce speed variations on highways.

<u>Summary of study by Solomon</u>

- Expected number of accidents was lowest at the mean speed. For two and four lane rural highways, the speed corresponding to the minimum number of accidents was found to be approximately 65 mph.
- Accident rates were higher in the night time than daytime.
- As the variation from average speed changes (either in the positive or negative direction), it increases the likelihood of an accident occurring.
- Accident severity increases with increased speed on rural roads.

Cirillo

Cirillo conducted a study to determine whether speed variance contributes to accident involvement on the Interstate System (5). This study may be seen as an extension to the study by Solomon. The difference was that Solomon's study focuses on only two and four lane rural highways while Cirillo investigated the contribution of speed variance to accidents in the Interstate System. Cirrilo used data collected by 20 state highway departments. Results of the analysis showed that, as the speed of a vehicle varies from mean speed of traffic, the chances of an accident involving the vehicle increase. The involvement rate versus variation from mean speed for interstate highways for Cirillo's study and its comparison with the Solomon's curve are shown in Figure 3.

<u>Summary of study by Cirillo</u>

- Extension of Solomon's study to observe if trends in the Interstate highways were similar. Similar trends found, i.e., as the variation from average speed changes (either in the positive or negative direction), it increases the likelihood of an accident occurring. Note that Cirillo found that variation up to 20 mph above the mean speed had little impact on involvement rate; however, variation in speed below the mean speed resulted in significant increases in involvement rate.

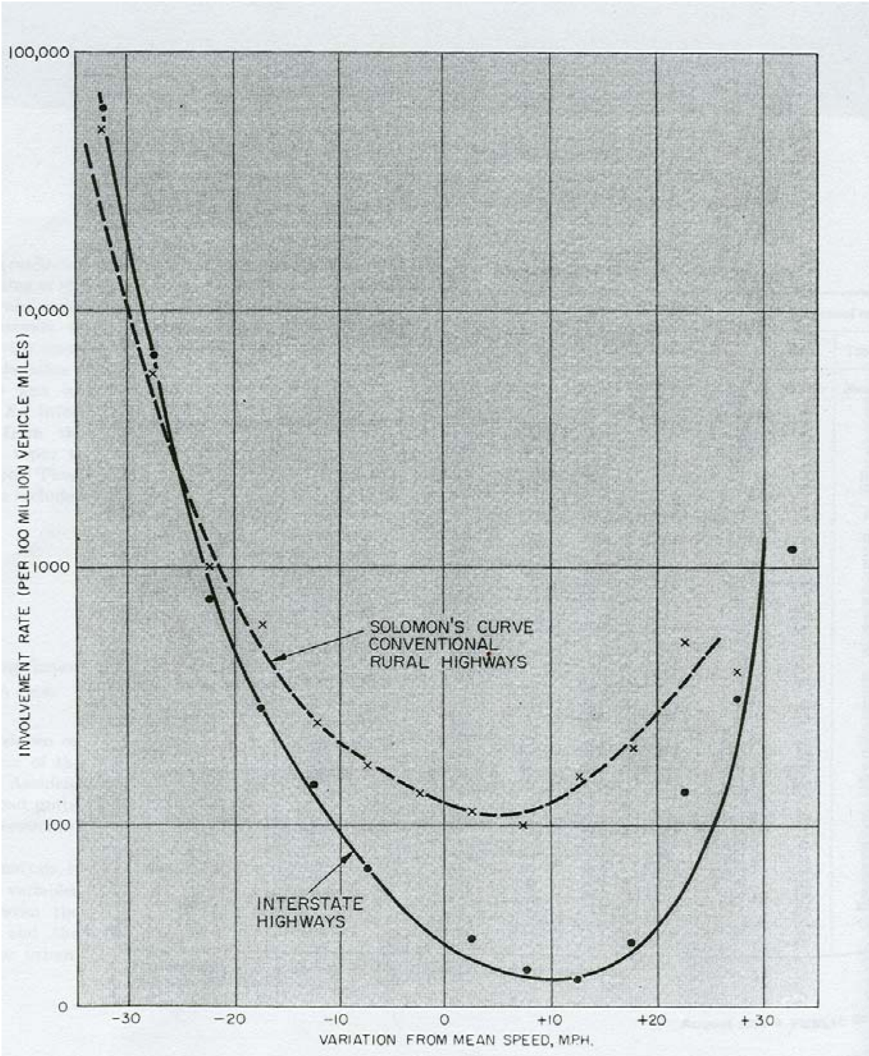

Figure 3 Cirillo's versus Solomon's Curve

Garber and Graham

Garber and Graham performed a study to examine the effect of the speed limit increase to 65 mph in 1987 (6). The researchers used monthly Fatal Accident Reporting System (FARS) data from January 1976 to November 1988 for their analysis. Using these data, they developed time series regression equations for each of the 40 states that had adopted the 65 mph speed limit. In their model, they attempted to control many other variables such as seat belt usage laws, seasonal variances, etc., that may affect highway safety. The researchers found that overall there was a 15 percent increase in fatalities on rural highways. However, when analyzed state by state, the fatalities increased in some states, decreased in other states and had no detectable effect in the remainder. The regression analysis yielded an increase in fatalities for 28 of the 40 states. Approximately 10 of these 28 states had a statistically significant increase. Of the 12 states that showed a decrease on fatalities, two had a statistically significant decrease.

Summary of study by Garber and Graham

- Examined the effect of the speed limit increase to 65 mph in 1987, for 40 states.
- Overall there was a 15 percent increase in fatalities in rural highways.
- When analyzed state by state, the fatalities increased in some states, decreased in other states and had no detectable effect in the remainder. Therefore, the specific safety effects of the increase in speed limit had varying effects by state. Further, little was done to control for the confounding effects associated with the speed and FARS data.

Lave and Elias

Lave and Elias analyzed the consequences of the speed limit increase that occurred in many states in 1987 (7). At that time, over 40 states had raised the speed limit to 65 mph on sections of their rural interstate roads. Since then, several studies evaluated the effect of the speed limit increase in 1987. Lave and Elias report that most of the studies simply looked at the number of fatalities before and after the increase of speed limit and this number usually increased. Instead, they argued, a better estimate would be to look at the rates, i.e., fatalities per vehicle miles traveled, which might tell a different story. The researchers further argue that many of the earlier studies were just confined into looking at the local effects of raising the speed limits. However, changing the speed limit is likely to have consequences for other roads in the state. For example, the enforcement needs could be reduced with the increase in speed limit due to better driver compliance. As a result, enforcement resources could be shifted to other safety activities. There may also be a shift of traffic from rural roads to the higher speed rural interstates, making rural roads safer. Lave and Elias suggested that these broader consequences should also be taken into account. In their study, Lave and Elias considered these issues in order to evaluate the consequences of the 1987 speed limit increase. They obtained statewide fatality data for 1 year before and one year after the 1987 speed limit change from the Fatal Accident Reporting System (FARS) database, as well as monthly vehicle miles traveled (VMT) data from Federal Highway Administration (FHWA) and the Nationwide Personal Transportation Survey. They used these data to perform three types of analysis.

First, the states were combined into two groups—one which raised the speed limit to 65 mph (test group) and the other that did not do so (control group). Researchers calculated the average change in overall fatality rates that occurred after the new speed limit and estimated that the decrease in fatality rate for the test group was 3.6 percent more than that of the control group. The researchers supported this result by performing a state by state regression analysis in which the dependent variable was fatality rate. The independent variables were kept the same as an earlier study by Garber and Graham (6). Key independent variables used included unemployment, seat belt laws, weekday/weekend patterns, etc. The most important independent variable was a dummy variable which was 0 in pre-65 mph months and 1 thereafter. This variable was important since its purpose was to determine the effect that speed change had on the fatality rate. If speed limit change did indeed impact the fatality rate, the regression equation would render this variable significant. All other independent variables were held constant. The analysis was done separately for each of the 65 mph states. The average decline in state-by-state fatality rates following the new speed limits was 3.4 percent and the dummy variable corresponding to speed limit change was significant in the regression equation. In order to check if this decline was the result of the new speed limit, the authors ran the same regression model on the 55 mph states, giving them fake 65 mph dummy variables from the date corresponding to the post 65 mph for the 65 mph states. In this case, there was no shift in fatality rates, thus giving strength to the hypothesis that the 3.4 percent decrease was indeed due to speed limit change in the 65 mph states.

Finally, the researchers also ran an analysis of the combined sample of 65 mph states and obtained a 5.1 percent decline in fatality rate. Using these results, the authors concluded that overall statewide fatality rates fell by 3.4 percent to 5.1 percent for the states that increased the speed limit to 65 mph.

Summary of study by Lave and Elias

- Studied the effect of 65 mph speed limit change in 1987 for several states.
- Looking at fatality rates rather than fatality frequency may be a better estimate for before and after speed limit change studies.
- Looking at global (i.e., fatality rates for entire state) rather than local effects (only fatality rates for selected highways with speed limit change) may provide a better understanding of the actual impact of speed limit changes.
- Looking globally, the statewide fatality rates for states with a speed limit change to 65 mph fell by 3.4 percent to 5.1 percent. States with no speed limit change did not undergo any significant changes in fatality rates.
- Only one year of data analyzed before and after speed limit change.

Ossiander and Cummings

Ossiander and Cummings evaluated the effects of increasing the speed limit in 1987 on rural freeways from 55 to 65 mph in Washington State (8). They analyzed data for fatal crashes, all crashes, fatalities and vehicle miles traveled on rural and urban interstate freeways in Washington State from 1970-1994. These data were acquired from the Washington State Traffic Safety Commission, along with the average and 85th percentile speed data. Researchers then used Poisson regression to analyze the association between fatal crash rate and speed limit increase. According to the researchers, Poisson regression is an appropriate method to use for data that follow a Poisson distribution. Since traffic accident counts commonly follow a Poisson distribution, Poisson regression was determine to be suitable for this analysis. Data from 1970-1994 were used for this analysis. Researchers found that fatal crash rates on Washington State's rural interstate was 110 percent higher after 1987 (when the speed limit was changed to 65 mph) than it would have been if the speed limit remained the same. However, the total crash rate showed little change implying that the share of crashes resulting in fatalities increased after the speed limit increase to 65 mph.

Ossiander and Cummings observed a large association between speed limit change and fatal crash rate. They also found that the increase in fatal crash rate in Washington was larger than was found in many other studies. One of the possible explanations for this was the large increase in average speed (from 58.5 mph before speed limit increase to 64 mph after speed limit increase). They contend that the effect of speed limit change is likely to depend on the change in vehicle speeds, and this change may differ substantially between states. The researchers also observed that the geography of Washington State is such that drivers rarely have a real choice between using the rural freeway or another highway. Thus, the effect of drivers being attracted from other roads onto the higher speed freeways and thereby improving the statewide impact of increasing speed limits (as suggested by Lave and Elias (5)) did not occur here.

In addition, the average and 85th percentile vehicle speeds increased on rural freeways after the speed limit increase, but there was negligible change in the speed variance. The researchers argued that this result does not support the view of setting speed limits at the 85th percentile speed in order to reduce speed variance. They observed that both slow and fast drivers seemed to be influenced by the new speed limits and increased their speed by about the same amount.

Summary of study by Ossiander and Cummings

- Studied the effect of speed limit change from 55 to 65 mph (1987) in Washington State.
- Fatal crash rates on Washington State's rural interstate was 110 percent higher after 1987 (when the speed limit was changed to 65 mph) than it would have been if the speed limit remained the same. However, the total crash rate showed little change implying that the share of crashes resulting in fatalities increased after the speed limit increase to 65 mph.
- Large association between speed limit change and fatal crash rate.
- Large increase in average speed (from 58.5 mph before speed limit increase to 64 mph after speed limit increase).
- Negligible change in the speed variance. Both slow and fast drivers seemed to be influenced by the new speed limits and increased their speed by about the same amount.
- Geography of Washington State is such that drivers rarely have a real choice between using the rural freeway or another highway. Thus the effect of drivers being attracted from other roads onto the higher speed freeways and thereby improving the statewide impact of increasing speed limits (as suggested by Lave and Elias (5)) did not occur here.
- Effect of speed limit change is likely to depend on the change in vehicle speeds, and this change may differ substantially between states.

Garber and Gadiraju

Garber and Gadiraju investigated the influence of different traffic engineering factors on speed variance (9). They selected sites for different highway types in Virginia (Urban and rural interstates, urban and rural arterials, rural major collectors) and collected traffic data (hourly volumes and individual vehicle speeds) and available accident data. Design speed was used as a surrogate for geometric characteristics and was obtained from the Virginia Department of Transportation. Accident data were obtained for 3 years (1983-1986) and included fatal, injury, property damage only and total accidents. Using these data, they developed regression models to determine several relationships. Their major findings were that accident rates increase with increasing speed variance for all classes of roads. Speed variance on a highway segment tends to be at a minimum when the difference between design speed and posted speed limit is between 5-10 mph (Figure 4) and the difference between design speed and posted speed limit has a statistically significant effect on speed variance. They also found that drivers tend to drive at increasing speeds as the roadway geometric characteristics improve, regardless of posted speed limits.

Summary of study by Garber and Gadiraju

- Investigated the influence of different traffic engineering factors on speed variance.
- Accident rates increase with increasing speed variance for all classes of roads.
- Difference between design speed and posted speed limit has a statistically significant effect on speed variance.
- Speed variance on a highway segment tends to be at a minimum when the difference between design speed and posted speed limit is between 5-10 mph.
- Drivers tend to drive at increasing speeds as the roadway geometric characteristics improve, regardless of posted speed limits.

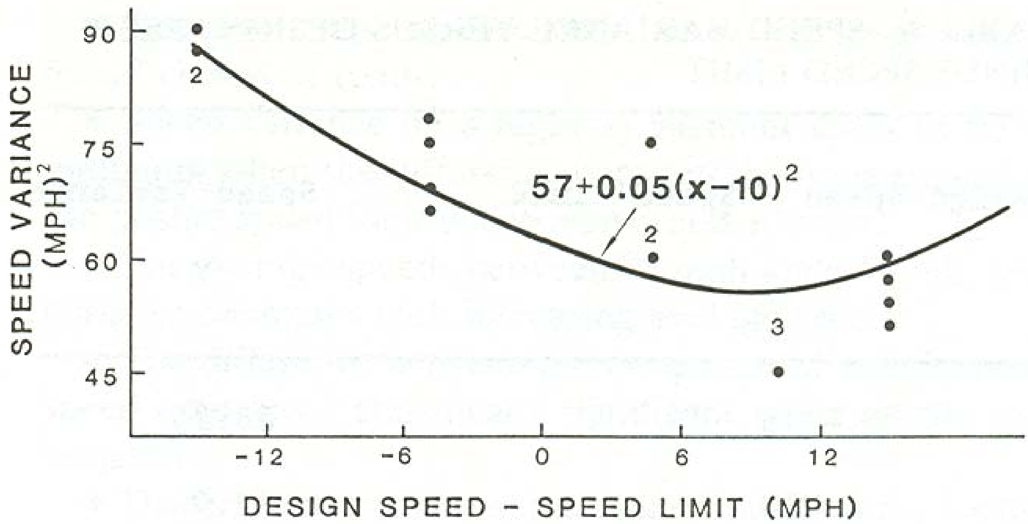

Figure 4 Garber Model

TRB Special Report 254

TRB Special Report 254 contains an extensive review on the effects of increasing the speed limit (1). Based on review of the available literature, the report concluded that higher speed limits introduced since 1987 resulted in higher average and 85th percentile speeds, and modest increases in speed variance. Most of the studies also found that higher speeds led to increased fatalities and fatal crashes on rural interstates in most states. However, the studies could not ascertain the absolute size of the safety decrement, and the extent and direction of any network effects. The report also describes the studies by Garber and Graham (6) and Lave and Elisas (7) discussed earlier. It also briefly mentions the fact that some researchers feel that the statewide data used by Lave and Elias may be too broad a measure of network effects. The TRB Special Report 254 acknowledges that the issue of system wide effects is an important topic that would require further research.

The report also investigates the study of limited data available for the first year following repeal of the NMSL in 1995. Based on the limited data, average and 85th percentile speeds rose less than the increase in posted speed limit. Speed variance increased in some states but not others. Most of the studies indicated an increase in fatalities on highways where speed limits were increased.

Summary of TRB Special Report 254

- Studies found that higher speeds limits lead to increased fatalities and fatal crashes on rural interstates in most states. But absolute size of safety decrement and the extent and direction of network effects are unclear.
- Issue of system wide effects of raising speed limits is an important topic that would require further research.

Balkin and Ord

Balkin and Ord performed a study to determine whether an increase in speed limit results in a higher incidence of fatal crashes (10). The method of analysis they used is called Structural Time Series Modeling. The advantage it has over other methods of Time Series Analysis is that using the structural approach, models can be set up explicitly in terms of components of interest such as trends, seasons and cycles. According to the researchers, this method is therefore superior since it incorporates the fact that environments that generate time series often do not remain constant. They used crash records from the Fatality Analysis Reporting System (FARS) maintained by National Highway Traffic Safety Administration (NHTSA) in order to extract monthly fatal crash data for each state, with separate counts for rural and urban interstates. Researchers considered all 50 states and extracted data from 1986 to 1998. The primary findings of their study were that almost half (19 out of 40) of the states studied experienced a significant increase in fatal crashes on rural interstates with the speed limit increase in 1987. Almost one third (10 out of 36) of the states studied experienced a significant increase in fatal crashes on rural interstates with the speed limit increase in 1995. The impact of the 1995 speed limit change was not as strong on urban interstates, with 6 out of 31 states experiencing a significant increase in fatal crashes. From their analysis, the researchers also observed a trend for a number of states. After the initial jolt of the speed limit change, the number of crashes tended to move back gradually towards levels prior to speed limit increase. The researchers acknowledge the fact that their analysis was not designed to examine the reason for this trend. Some of the possible explanations that they mention for this trend are:

1. Drivers adjusted to driving at higher speeds.
2. States increased enforcement of driving laws.
3. Automobile safety was improved.

<u>Summary of study by Balkin and Ord</u>

- Study objective was to determine whether an increase in speed limit resulted in a higher incidence of fatal crashes.
- Covered all 50 states and extracted data from 1986 to 1998.
- Almost half (19 out of 40) of the states studied experienced a significant increase in fatal crashes on rural interstates with the speed limit increase in 1987.
- Almost one third (10 out of 36) of the states studied experienced a significant increase in fatal crashes on rural interstates with the speed limit increase in 1995.
- Impact of the 1995 speed limit change was not as strong on urban interstates, with 6 out of 31 states experiencing a significant increase in fatal crashes.
- After the initial jolt of the speed limit change, the number of crashes tended to move back gradually towards levels prior to speed limit increase.
- Analysis was based on fatal crashes, not crash rates.

Iowa Study

This study was conducted to determine the long term safety effects and benefits of raising speed limits on high speed roads (11). Over 355 miles of rural, four lane divided freeways and expressways were reviewed by Iowa DOT for increase in speed limit from 55 mph to 65 mph in 1996. After the review, speed limits were increased in 248 miles of highway. The study had several findings.

First, the 85th percentile operating speeds in Iowa's rural expressways and freeways increased an average of 8.2 mph (from 61.6 to 69.8 mph) when comparing the '1993-1996' period to '1996-2001' period. This corresponded to a speed limit increase of 10 mph. More drivers complied with this speed limit as 71 percent of drivers exceeded the speed limit prior to speed limit increase versus 50percent after the speed limit increase. However, the speed variance increased from 7.9 mph before speed limit increase to 9-10 mph after speed limit increase.

Crash related findings showed an increase in all types of crashes after the speed limit increase. This is summarized in Table ES-1 below. The study also looked at the rural interstate fatalities of other states surrounding Iowa. The states that were studied and the results are summarized in Table ES-2. This table shows the annual average fatal crashes per year increased for all the states that increased their speed limits, when the fatal crashes before the speed limit increase were compared with fatal crashes after speed limit increase.

Table ES-1 Crash and Injury Rate Comparisons on Iowa's Expressways

	"Before" Rates Per HMVM*	"After" Rates Per HMVM*	Percent Change
Fatal Crashes	0.30	1.79	+ 497%
Fatal and Injury Crashes	25	32	+ 28%
All Crashes	77	97	+ 26%
Fatalities	0.30	2.06	+ 587%
Fatalities Plus Major Injuries	5.1	8.7	+ 71%
Other Less Severe Injuries	35	42	+ 20%

Rates Per Hundred Million Vehicle Miles (HMVM)

* "Before" rates are based on composite totals from the 1993 through 1996

Table ES-2 Rural Interstate Fatalities in Iowa and Surrounding States

State	Limit Change	1993-1995 Annual Avg.	1996-2001 Annual Avg.	Percent Change
Iowa	No, 65 mph	32.0	31.0	- 3%
Minnesota	Yes, 70 mph	19.5	25.3	+ 30%
Missouri	Yes, 70 mph	125.0	173.6	+ 39%
Nebraska	Yes, 75 mph	19.7	31.2	+ 58%
South Dakota	Yes, 75 mph	15.0	16.2	+ 8%

Table ES-3 shows a comparison of the total traffic fatalities in states that raised the speed limit and states that did not raise the speed limits. The results in this table seems to further underscore the fact that increase in speed limit can cause a detrimental effect to the number of traffic fatalities.

Table ES-3 Change in Total Traffic Fatalities from 1991-1995 to 1996-2000

States That Did Not Change Speed Limits Above 65 mph		States That Did Change Speed Limits Above 65 mph	
Iowa	- 3.0%	Kansas	+ 14.0%
Illinois	- 3.0%	Minnesota	+ 6.0%
Wisconsin	+ 3.0%	Missouri	+ 11.0%
		Nebraska	+ 12.0%
		South Dakota	+ 7.0%
Overall Change	- 1.3%	Overall Change	+ 10.2%

Summary of Iowa study

- Study evaluated the long term safety effects and benefits of raising speed limits from 55 mph to 65 mph in Iowa (1996).
- The 85th percentile operating speeds in Iowa's rural expressways and freeways increased an average of 8.2 mph (from 61.6 to 69.8 mph) when comparing the '1993-1996' period to '1996-2001' period.
- Speed variance increased from 7.9 mph before the speed limit increase to 9-10 mph after the speed limit increase.
- Crash rates for the expressways were analyzed before and after the speed limit increase. There was an increase in all types of crashes after the speed limit increase.
- For other states surrounding Iowa, total traffic fatalities in states that raised the speed limit was higher than states that did not raise the speed limits.

Bartle et al

Bartle et al conducted a study to determine if the raising of speed limit to 70 mph on rural interstate highways in the state of Alabama had any influence on the number of *motor vehicular crash* (MVC) deaths (12). Alabama increased the maximum speed limit on rural interstate highways from 65 mph to 70 mph, and to 65 mph on urban interstate highways in May, 1996. Bartle investigated whether the increase in the speed limit on Alabama interstate highways in 1996 had any effect on MVC fatalities per year over the following two years. Researchers used the traffic accident and fatality data published by the State of Alabama and the traffic volume data (to calculate annual vehicle miles traveled) from the Alabama Department of Transportation. Using these data, they calculated the annual MVC fatality rate for the years 1984 through 1999. Researchers then used these data to perform a time series analysis to examine the MVC deaths before and after the speed change (as mentioned earlier the speed limit change occurred in May 1996). Researchers found that deaths from MVC increased on Alabama roads over the years from 1984 to 1999. There was a significantly higher number of MVC fatalities in 1997 (right after the speed limit increase) and again in 1999. However, in 1998 there was a decline in MVC fatalities. Bartle et al were unable to give a clear explanation of why there was a decline, but they came up with several possible explanations ranging from regression to the mean effect to 'readjustment in driver proficiency'. What is highlighted by this study is that two out of the three years after the speed limit increase, fatalities attributed to MVC's were significantly higher. Bartle et al point out this fact in their conclusion but also mention that further studies from other states would better help to generalize their results.

Summary of study by Bartle et al

- Objective of the study was to determine if the raising of speed limit to 70 mph on rural interstate highways (1996) in the state of Alabama had any influence on the traffic fatality.
- Fatalities attributed to MVC's were significantly higher in two out of the three years analyzed after the speed limit increase, when compared to the fatalities before speed limit increase.

Monsere et al

Monsere et. al conducted a review to investigate the effect of raising the speed limit (2). Their investigation was sponsored by the Oregon Department of Transportation and arose out of the revisions enacted by the 2003 Oregon Legislature. At that time, the Oregon Legislature authorized a maximum posted speed of 70 mph for passenger cars and 65 mph for trucks, while the existing maximums were 65 mph for passenger cars and 55 mph for trucks. The law did not directly raise the speed limits but required the Oregon Department of Transportation to conduct a study to determine safe and reasonable speed limits. Monsere et. al conducted an extensive literature review prior to their analysis. Their findings are summarized below:

1. Effect of changing speed limit on travel speeds of passenger cars:
Monsere et. al found that studies of states that have changed their speed limits from 65 mph to 70 mph have seen a 2 to 7 mph increase in the average and the 85^{th} percentile speed limit. Another phenomenon that the speed limit change may result in is speed adaptation. Speed adaptation is the theory that higher speed on interstates promote driver acceptance of speed, which they transfer to other roadways. Essentially, this results in a speed spillover from the higher speed interstate roads to lower speed roads. Monsere et al reviewed several studies which led them to conclude that drivers' perception of their own speed is less than their actual speeds after traveling at higher speeds. However, this effect decays the longer the driver is on the slower roadway. What is not clear is the length of time that the speed adaptation effect persists. Based on the abovementioned literature, Monsere et. al are of the opinion that for a speed limit change from 65 to 70 mph, there would be speed adaptation for short sections of facilities adjacent to the interstates, but a measurable change in speeds of vehicles on all adjacent roadways is not likely.

2. Effect of changing speed limit on frequency and severity of crashes:
Monsere et al reviewed several studies that have shown increases in crash fatalities ranging from no effect to a 35 percent increase. Monsere reports that in most of the above studies, increases in speed limit result in increases in fatalities. Considering all the information and studies, Monsere concluded that a reasonable estimate of the increase of the number of fatalities on the interstate highway system is a 5-15 percent increase if the speed limits are raised to 70 mph. He also estimated the major injury crashes to increase by the same amount.

Based on their review, Monsere concluded that with the exception of travel time savings for passenger cars and trucks, all other issues would be negatively impacted by the proposed speed limit changes.

<u>Summary of study by Monsere et al</u>

- Performed a literature review to investigate the effect of raising speed limit
- Studies of states that have changed their speed limits from 65 mph to 70 mph have seen a 2 to 7 mph increase in the average and the 85th percentile speed limit.
- For a speed limit change from 65 to 70 mph, a speed adaptation for short sections of facilities adjacent to the interstates is expected, but a measurable change in speeds of vehicles on all adjacent roadways is not likely.
- Based on the literature reviewed, it is estimated that an increase of the number of fatalities on the interstate highway system may be 5-15 percent associated with a change to 70 mph. Major injury crashes are estimated to increase by the same amount.
- No data were collected to support these fatality and injury increase predictions.

Vernon et al

Vernon et al conducted a study to evaluate the effect of increasing the speed limit (mostly to 65 mph and some to 70 mph) on Utah highways, on injury and fatal crashes (13). They performed a time series statistical analysis of traffic and crash data of Utah highways from 1992 to 1999. The research found total crash rates on urban Interstates to be significantly greater than predicted after increasing speed limits in 1996. However, this conclusion was confounded by the major Interstate reconstruction project that commenced in April 1996. For non-interstate highways, researchers found a significant increase in the rate of fatal crashes for the highways that had a speed limit increase. In contrast, highways with no speed limit change showed no change in fatal crash rates. However, in both cases, the total crashes and injury crashes remained the same.

There are two issues worthy of note in the above analysis. First, similar to many other studies, the period after the speed limit change was fairly short suggesting caution in interpretation of results. Second, the fact that the total crashes and injury crashes remained the same for the non-interstate highways, but the fatality crashes increased significantly, could presumably be attributed effect of the physics in crashes due to higher speeds. This could lead to a lower number of 'vehicle damage only' crashes but increased number of fatality crashes, since the impact of the vehicles may now have more serious consequences due to increased speeds.

<u>Summary of study by Vernon et al</u>

- Objective was to evaluate the effect of increasing the speed limit (mostly to 65 mph and some to 70 mph) on Utah highways on injury and fatal crashes.
- Total crash rates on urban Interstates were significantly greater than predicted after increased speed limits in 1996. However, this conclusion was confounded by a major Interstate reconstruction project at that time.
- For non-interstate highways, there was a significant increase in the rate of fatal crashes for the highways that had a speed limit change. In contrast, highways with no speed limit change showed no change in fatal crash rates.

Patterson et al

Patterson et al conducted a before and after analysis to model rural interstate fatalities between 1992 and 1999 for three groups- no speed limit change, change to 70 mph and change to 75 mph (14). Researchers looked at the fatalities and VMT of the states displayed in Table II and divided them into the 3 aforementioned groups, namely states with 'no speed limit change' (speed limit static at 65 mph), those with 'change 70 mph' (speed limit changed from 65 mph to 70 mph) and those with 'change 75 mph'(speed limit changed from 65 mph to 75 mph). Note that Wisconsin fell into the first category.

Table II The three groups of states and those excluded from a group

"No-change 65 mph"	"Change 70 mph"	"Change 75 mph"	Excluded
Alaska	Alabama	Arizona	Connecticut
Illinois	Arkansas	Colorado	Delaware
Indiana	California	Idaho	District of Columbia
Iowa	Florida	Nebraska	Hawaii
Kentucky	Georgia	Nevada	Louisiana
Maine	Kansas	New Mexico	Maryland
New Hampshire	Michigan	Oklahoma	Massachusetts
Ohio	Mississippi	South Dakota	Minnesota
Oregon	Missouri	Utah	Montana
Vermont	North Carolina	Wyoming	New Jersey
Virginia	North Dakota		New York
Wisconsin	Washington		Pennsylvania
			Rhode Island
			South Carolina
			Tennessee
			Texas
			West Virginia

Figure 5 shows the rural interstate fatality rates by speed limit change group. The results indicate that the 'no change 65 mph group' consistently had a lower fatality rate between 1992 and 1999 when compared to the other two groups. It also indicates that the difference between the groups appear larger from 1996 when compared to the earlier years. Recall that in November 1995, the federal government returned speed limit authority to the states.

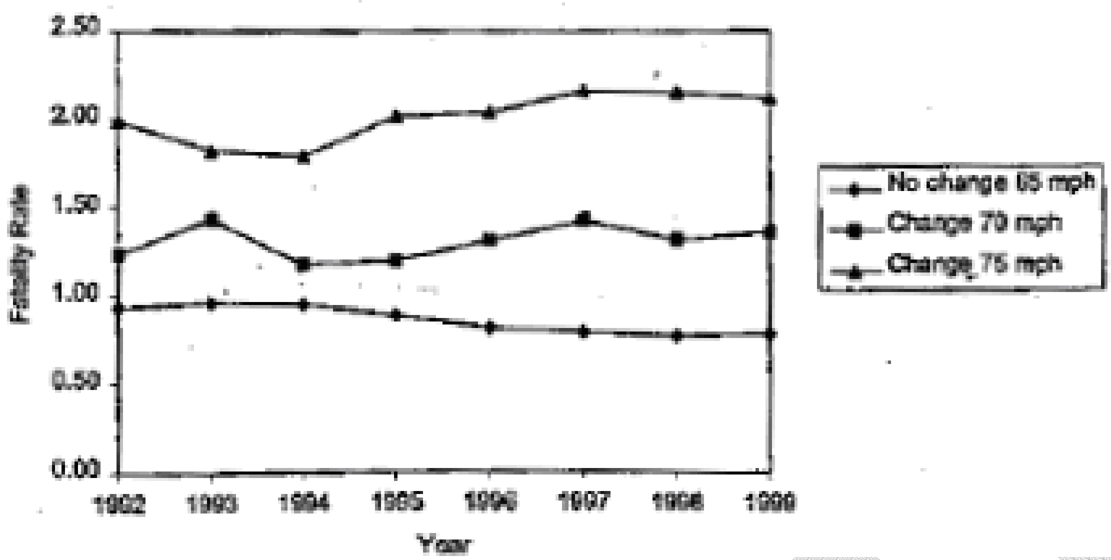

Figure 5 Fatality Rate by Speed Limit Change Group

Patterson et al fitted regression models in order to determine if the difference was significant. Based on this analysis, they concluded that in the four years since 1996, 'states that increased their rural interstate speed limits had higher fatality rates than would have been expected based on the fatality rates in the states that kept their rural interstate speed limits at 65 mph'. Patterson et al surmised that raising the interstate speed limit is the more likely reason for this increased fatality rate. However, he also acknowledge the fact the there may have been other possible explanations. One of the possible explanations could be regional factors, since the 65 mph states tended to be in the Northeast, 70 mph states in the South and 75 mph states in West.

Summary of study by Patterson et al

- Before and after analysis to model rural interstate fatalities between 1992 and 1999 for three groups- no speed limit change, change to 70 mph and change to 75 mph.
- States that increased their rural interstate speed limits had higher rural interstate fatality rates than would have been expected based on the fatality rates in the states that kept their rural interstate speed limits at 65 mph.

Joksch

Joksch used accident data from the National Accident Sampling System (NASS) to estimate the probability that a driver is killed in a vehicle crash versus the velocity change of the vehicle in the crash (15). The results demonstrated that the fatality risk increased with increased velocity change of the vehicle in the crash. Fatality risk was proportional to the fourth power of the change in speed as presented in the equation below. Joksch also found that the fatality risk in a crash increases with the speed limit of the highway.

Probability of fatality = $(\Delta V/71)^4$

<u>Summary of study by Joksch</u>

- Objective was to determine the relation between fatality risk and velocity change of the vehicle in the crash.
- The fatality risk was proportional to the fourth power of the change in speed.
- Fatality risk in a crash increases with the speed limit of the highway.

McCarthy

McCarthy conducted an extensive literature survey in order to evaluate the effect of motor vehicle speed limits on highway speeds and safety (16). This report is published as an appendix in the TRB special report 254 (1). Based on the literature survey concerning the effect on speed distributions of increasing speed limits from 55 mph to 65 mph, the following are some of the relevant conclusions that can be drawn:

1. On nonlimited-access roads, evidence suggests that changes in speed limits affect average speed and speed variance, but the magnitude of these changes appears to be small, and possibly much smaller than the change in speed limit.
2. Drivers exhibit speed adaptation, but the difference between adapted and non-adapted speeds is less than 5 percent. The extent of speed adaptation appears not to worsen with increasing speed limits.
3. On limited-access high speed roads, work indicates that increased speed limits lead to higher average speeds (4 mph or less for 10 mph speed limit increase) and increased 85th percentile speeds (4 mph or less for 10 mph speed limit increase) with small increases in speed dispersion (by less than 1 mph).
4. There is positive relationship between crash severity and speed dispersion, particularly for rural Interstate roads. There is evidence to suggest that minimum speed dispersion occurs when the difference between a roads design speed and posted speed limit lies between 5 and 10 mph.
5. More detailed and informative data is required to better understand the relationship between average speed, speed dispersion and highway safety.
6. Most studies conclude that highway safety deteriorated with the increase of rural Interstate highway speeds from 55 to 65 mph, but at the same time most of these studies are unable to adequately control for other factors that determine rural Interstate fatalities and fatality rates.
7. Many of the studies occurred in late 1980’s and early 1990’s with relatively few studies in late 1990’s.
8. For limited access roads, both average speed and speed dispersion are inversely related to highway safety in general and fatalities in particular. Drivers traveling in the top 15 percentile appear to compromise safety more than drivers traveling in the lowest 15th percentile.

Synthesis of Human Factors Research on Older Drivers

This synthesis reviews the literature associated with driver performance and highway operations (17). According to the review, there is a large and growing body of literature regarding the capabilities and limitation of older drivers that affect their ability to negotiate the highway safely, from the standpoint of highway operations. The decline of drivers’ capabilities as they age has now been well established. Some of the very common problems associated with aging pertinent to driving ability include degradation of visual acuity, lowered contrast sensitivity, diminished information processing capabilities, increased complex reaction times, etc. The review goes on to report that there is considerable 'anecdotal' information in many studies that older drivers drive more slowly than younger drivers. This is intuitive since older drivers seek to compensate their declined driving capabilities with the additional time they would get to react of they drive slower. Strength to these claims have also been given by the study of traffic violation data related to accidents, where older drivers were less likely than other age groups to be cited for speed related offences when they were involved in crashes. However, the review also reports that there were no comprehensive studies that explicitly compared the speeds of older drivers to other drivers. The review cited one study by Walker et al (1990) where, in a simulator based experiment, it was found that older drivers drove more slowly and were more likely to make navigational errors.

Summary of Synthesis of Human Factors Research on Older Drivers

- Common problems associated with aging pertinent to driving ability include degradation of visual acuity, lowered contrast sensitivity, diminished information processing capabilities, increased complex reaction times, etc.
- No comprehensive studies that explicitly compared the speeds of older drivers to other drivers, there is considerable 'anecdotal' information in many studies that older drivers drive more slowly than younger drivers.

National Survey

This NHTSA survey considers driver behavior with regards to speeding and speed limit (18). NHTSA first conducted a study on the driving public's attitudes and behaviors regarding speeding and unsafe behaviors in 1997. In 2002, NHTSA undertook a second survey of drivers to collect updated data on the nature and scope of the speeding and unsafe driving problem with the intent of understanding how serious the problem is in the public's eye, and what measures the public may accept to counter these problems. Some of the key findings related to driver attitudes about speed limits are:

- Drivers seem to believe they can drive 7-8 mph over speed limit.
- While the vast majority of drivers on various road types feel that speed limits on two-lane roads (78%) and city, town, or neighborhood streets (83%) are about right, more than one third (35%) feel that speed limits on the interstate highways that they drive on are too low. More than one in five (22%) feel limits on non-interstate multi-lane roads are also too low.
- Drivers see the average "ideal" speed limit for interstate highways at around 67 MPH, though half feel the limit should be 70 MPH or higher.
- Even if current speed limits were increased by 10 MPH, nearly four in ten (38%) drivers of interstate highways predict they would drive at least a little bit faster than the new posted speed limit.

SPEED LIMIT INCREASE AND TRAFFIC SAFETY

Based on review of the above literature, some of the key potential issues associated with speed limit increase and traffic safety are discussed below.

Impact of Speed Limit on Speed Variance

The U-shaped relationship developed by Solomon between likelihood of accident and variation of speed is well established (4, 5). According to this relation, as the variation in travel speeds increases, there is a greater likelihood of crash. Reducing the speed variance is therefore one of the key requirements for reducing traffic crashes. The big question is- how would an increase in speed limit from 65 mph to 70 mph in freeways and expressways affect speed variance? Garber and Gadiraju (9) provided evidence based on their study that speed variance on a highway segment tends to be minimum when the difference between design speed and posted speed is between 5-10 mph. Other studies (8, 11) have shown that increases in speed limit have resulted in increases in average speed and negligible or slight increase in speed variance. However, these other studies do not explicitly mention the design speed of the highway segment. According to McCarthy (16), there is evidence that changes in speed limits affect average speeds and speed dispersions, but the magnitude of these changes appear to be small, and possibly much smaller than the speed limit. Therefore, based on the literature reviewed, it is unlikely that a 5 mph increase in speed limit would have a considerable affect on speed variance.

Physics/Crash Force Difference for a 5 mph Change from 65 to 70 mph

There have been studies that have investigated the relation between accident severity and speed. One of the findings of Solomon's study (4) was that crash severity increases with increased speed on rural roads and the probability of a fatal injury rises sharply for speeds over 70 mph. Joksch (15) found that fatality risk was proportional to the fourth power of the change in speed of a vehicle in a crash and that that the fatality risk increases with speed limit.

A simple analysis was performed to estimate the force differences for a 5 mph speed change from 65 mph to 70 mph. The average curb weight of a mid size 4-door passenger vehicle is reported by NHTSA (19) to be around 3000 pounds. Assuming a vehicle weight of 3000 pounds, an increase from 65 to 70 mph would result in a 16% increase in Kinetic Energy. The amount of energy added as a result of a velocity change of 5 mph from 65 mph to 70 mph would be equivalent to a 3000 pound vehicle traveling at 26 mph and hitting a static object, or a person weighing 200 pounds falling 335 feet. This additional energy could well mean the difference between life and death at high velocity collisions. APPENDIX II contains an embedded Excel object showing the above calculations. Other vehicle weights and speeds can also be input in this object to view the Kinetic Energy change and equivalent speed.

Older Drivers

No comprehensive studies were found that explicitly compared the speeds of older drivers to other drivers. However, there is sufficient evidence supporting the fact that driving ability deteriorates with aging due to degradation of visual acuity, lowered contrast sensitivity, diminished information processing capabilities, increased complex reaction times, etc. There is considerable 'anecdotal' information in many studies that older drivers drive more slowly than younger drivers (17). Strength to these claims have also been given by the study of traffic violation data related to crashes, where older drivers were less likely than other age groups to be cited for speed related offences when they were involved in crashes. It is therefore reasonable to assume that older drivers would be more likely to compensate for diminished driving ability by driving at a slower speed. It is likely that as the speed limit is increased, the difference between the average speed and the speed of older drivers would increase, resulting in increased speed variance.

Mean Speed of Drivers

Evidence suggests that states that have increased their speed limit from 65 mph to 70 mph have seen a 2 to 7 mph speed increase in average and 85th percentile speed (2). As observed in several studies (2, 8, 11, 16), no clear prediction in the extent of increase can be given. There could be several reasons for this variation in the 85th percentile speed in different studies. Driving habits, enforcement levels, socioeconomic factors, geographical factors, weather, and road characteristics could be some of them. No studies were found that explicitly examined the maximum 85th percentile speed beyond which drivers would not feel comfortable. A national survey (18) showed that drivers currently seem to believe that they can driver 7-8 mph over speed limit. Drivers see an ideal speed at around 67 mph, although half the drivers interviewed felt that the speed limit in freeways and expressways should be 70 mph or higher. Judging by the 85th percentile speeds observed in the literature reviewed and from the driver surveys, it seems likely that the driver 'comfort' speed (beyond which most drivers would not tend to travel) lies somewhere between 70 and 75 mph. However, additional research is required to provide more definitive answers.

Impact of Raising Speed Limits on Traffic Crashes

Studies pertaining to the increase in speed limit for highways generally show an increase in fatalities (6, 8, 10, 11, 12, 13, 14) both for the 1987 speed limit increase and 1995 speed limit increase. However, many of these studies are unable to control all the factors associated with highway fatality and fatality rates. Lave and Elias (7) rightly pointed out that global effects need to be considered instead of local effects to truly evaluate the effect of raising speed limits. Their statewide evaluations for different states indicated that fatality rates actually fell on an average by 3.4 percent to 5.1 percent for the 65 mph speed limit change in 1987. However, according to the TRB Special Report 264, (1) there are other researchers who feel that statewide data is too broad a measure of network effects. State geography is also an issue that needs to be considered to evaluate the global effects, as pointed out by Ossiander and Cummings (8). The geography of the state may be such that drivers rarely have a choice between using the rural freeway or another highway.

In summary, what has been established from prior research is that increasing the speed limit of a highway may likely result in an increase in traffic fatalities for that highway, i.e., local increase in traffic fatalities. What has not been established is the extent of global effects resulting from these speed limit increases as pointed out by Lave and Elias (7). Research is essential to effectively determine the global effect of raising speed limit.

CONCLUSIONS

Based on the literature reviewed, raising the speed limits from 65 mph to 70 mph on Wisconsin's freeways may result in an initial increase in speed-related traffic fatalities. However, the extent of this increase can not be precisely estimated based on historical data. It is not clear whether this increase of freeway fatalities would be offset by a lower number of fatalities on other roads in Wisconsin. Therefore, it is not clear whether increasing the speed limit will result in an overall increase or decrease in fatalities. If the speed limits on freeways in Wisconsin are to be increased, a phased approach may be considered over a period of several years. Research can accompany the speed limit changes to clearly document the effects.

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APPENDIX I

State	Rural Interstates	Urban Interstates	Other Limited Access Roads	Other Roads	Effective Date of Limits on		Effective Date of Limits on	
	Cars (mph)	Cars (mph)	Cars (mph)	Cars (mph)	Rural Interstates	Urban Interstates	Other Limited Access Roads	Other Roads
Alabama	70	65	65	65	5/21/96	5/21/96	5/21/96	5/21/96
Alaska	65	55	65	55	1/15/88	no action	8/25/99	no action
Arizona	75	55	55	55	12/8/95	no action	no action	no action
Arkansas	70 trucks: 65	55	60	55	8/19/96	no action	8/19/96	no action
California	70 trucks: 55	65	70	65	1/8/96	1/8/96	1/8/96	no action
Colorado	75	65	65	65	6/24/96	6/24/96	6/24/96	no action
Connecticut	65	55	65	55	10/1/98	no action	10/1/98	no action
Delaware	65	55	65	55	1/17/96	no action	1/17/96	no action
District of Columbia	N/A	55	N/A	25	1974	no action	no action	no action
Florida	70	65	70	65	4/8/96	4/8/96	4/8/96	4/8/96
Georgia	70	65	65	65	7/1/96	7/1/96	7/1/96	7/1/96
Hawaii	60	50	45	45	1974	no action	no action	no action
Idaho	75 trucks: 65	75	65	65	5/1/96	5/1/96	5/1/96	5/1/96
Illinois	65 trucks: 55	55	65	55	1/25/96	no action	1/25/96	no action
Indiana	70 trucks: 65	55	60	55	7/1/05	no action	7/1/05	no action
Iowa	70	55	70	55	7/1/05	no action	7/1/05	no action
Kansas	70	70	70	65	3/7/96	3/7/96	3/7/96	3/7/96
Kentucky	65	65	65	55	6/8/87	no action	no action	no action
Louisiana	70	70	70	65	8/15/97	8/15/97	8/15/97	8/15/97
Maine	65	65	65	60	6/12/87	6/12/87	6/12/87	6/12/87
Maryland	65	65	65	55	7/1/95	8/1/96	8/1/96	no action
Massachusetts	65	65	65	55	1/5/92	1/29/96	1/29/96	no action
Michigan	70 trucks: 55	65	70	55	8/1/96	8/1/96	8/1/96	no action
Minnesota	70	65	65	55	7/1/97	7/1/97	7/1/97	no action
Mississippi	70	70	70	65	2/29/96	2/29/96	2/29/96	2/29/96
Missouri	70	60	70	65	3/13/96	3/13/96	3/13/96	3/13/96
Montana	75 trucks: 65	65	day: 70 night: 65	day: 70 night: 65	5/28/99	5/28/99	5/28/99	5/28/99
Nebraska	75	65	65	60	9/1/96	9/1/96	9/1/96	9/1/96
Nevada	75	65	70	70	12/8/95	12/8/95	12/8/95	12/8/95

New Hampshire	65	65	55	55	4/16/87	5/29/96	no action	no action
New Jersey	65	55	65	55	1/19/98	no action	1/19/98	no action
New Mexico	75	75	65	55	5/15/96	no action	5/15/96	no action
New York	65	65	65	55	8/1/95	7/16/96	7/16/96	no action
North Carolina	70	70	70	55	8/5/96	8/5/96	10/1/96	no action
North Dakota	75	75	70	65	8/1/03	8/1/03	8/1/03	8/1/03
Ohio	65 trucks: 55; 65 on Ohio Turnpike	65	55	55	7/15/87	7/28/96	no action	no action
Oklahoma	75	70	70	70	8/29/96	8/29/96	8/29/96	8/29/96
Oregon	65 trucks: 55	55	55	55	6/27/87	no action	no action	no action
Pennsylvania	65	55	65	55	7/13/95	no action	5/10/96	no action
Rhode Island	65	55	55	55	5/12/96	no action	no action	no action
South Carolina	70	70	60	55	4/30/99	4/30/99	4/30/99	no action
South Dakota	75	75	65	65	4/1/96	4/1/96	4/1/96	4/1/96
Tennessee	70	70	70	65	3/25/98	5/15/01	5/15/01	5/15/01
Texas	day: 75 night: 65 trucks: 65	day: 70 night: 65	day: 75 night: 65 trucks: 65	day: 60 night: 55	9/1/99	9/1/99	9/1/99	9/1/99
Utah	75	65	75	65	5/1/96	5/1/96	5/1/96	5/1/96
Vermont	65	55	50	50	4/21/87	no action	no action	no action
Virginia	65	65	65	55	7/1/88	7/1/01	2/13/96	no action
Washington	70 trucks: 60	60	60	60	3/15/96	3/15/96	3/15/96	3/15/96
West Virginia	70	55	65	55	8/25/97	no action	8/25/97	no action
Wisconsin	65	65	65	55	6/17/87	8/1/96	8/1/96	no action
Wyoming	75	60	65	65	12/8/95	12/8/95	12/8/95	12/8/95

APPENDIX II

(Values in the three boxes below can be edited for this Excel object. Double click on object to modify)

Enter Values only for the **Bold** highlights

Enter weight of vehicle in pounds:	3000	
Equivalent kilogram weight=	1363.63636	
Enter speed 1 of vehicle (mph):	65	
Enter speed 2 of vehicle (mph):	70	
Speed 1 in meters per second=	28.88889	meters/sec
Speed 2 in meters per second=	31.11111	meters/sec
Kinetic energy associated with Speed 1 and given mass=	569.0236	Kilo Newton
Kinetic energy associated with Speed 2 and given mass=	659.9327	Kilo Newton

Change in Kinetic Energy (2-1)
= 90909.09 Newton

% increase in Energy
= 15.97633 %

Equivalent velocity in meters/sec for given mass and Kinetic Energy Change
= 11.54701 meters/sec

Equivalent velocity in miles/hr for given mass and Kinetic Energy Change
= 25.98076 mph