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16. Abstract

The repeal of the National Maximum Speed Limit Law (NMSL) in 1995 permitted States to set speed limits within their own borders. As a results, speed limits were increased in some areas, from 55 mph to 60 or 65 mph on urban Interstates, from 65 mph to 70 or 75 mph on rural Interstates, and from 55 mph to 60 or 65 mph on some stretches of rural non-Interstate highways. This study evaluates the effect of the increased speed limit on Utah highways on crash rates, fatality crash rates, injury crash rates, linkage of crashes to hospital inpatient files, and hospital inpatient charges related to crashes. Population-based data on crashes and hospital inpatient files were linked using probabilistic methods and joined with speed limit and vehicle traffic volume data. Annual (1992-1999) rates of crashes, fatality crashes, and injury crashes for the following highway categories were calculated: Urban Interstate segments (current speed limit 60-65 mph); rural Interstate segments (current speed limit 70-75 mph); low-speed non-Interstate highway segments (current speed limit ≤50 mph); 55 mph rural non-Interstate highway segments; and high-speed non-Interstate highways (current speed limit 60-65 mph). Data were analyzed using autoregressive integrative moving average intervention time series analysis techniques. Findings included significant increase in total crash rates on urban (60-65-mph) urban Interstate segments, and a significant increase in fatal crash rates, and the proportion of crashes associated with a fatality, on high-speed (60-65-mph) rural non-Interstate segments. The following variable were unaffected: Total, fatality, and injury crash rates on rural Interstate segments; fatality and injury crash rates on urban Interstate segments; total and injury crash rates on high-speed non-Interstate segments; rates of linkage of crash files to hospital inpatient files (reflecting the likelihood of a crash being associated with a hospitalization); and total and per-crash hospital inpatient charges. These results show an adverse effect on crash occurrence for subsets of crash types and highways, but do not show a major overall effect of NMSL repeal and increased speed limit on crash occurrence on Utah highways.

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Executive Summary

The National Maximum Speed Limit Law (NMSL) originated in 1973, when an oil embargo in the Middle East resulted in serious shortages of fuels in the United States. The NMSL was conceived as an energy-saving measure and was initially 55 miles per hour (mph) nationwide. Following the enactment of the NMSL, the annual number of national traffic crash fatalities decreased, from 54,000 in 1973 to 45,000 in 1974. This was attributed to the decrease in speed limits, and in response, Congress made the change in national speed limits permanent. It became accepted at this time that reduction in speed limit was a powerful method of reducing motor vehicle crashes and associated injuries and fatalities. As time passed, however, support for the NMSL gradually weakened for a variety of reasons, including the cessation of the fuel shortage, recognition that a large proportion of drivers were exceeding the posted limits, and concerns about States' rights to set speed limits within their own borders. The NMSL was altered in 1987, when States were allowed to raise the speed limit to as high as 65 mph on certain rural Interstates. Opposition to a national speed limit persisted, despite data from the National Highway Traffic Safety Administration suggesting that the increase to 65 mph led to an increase in crash-related fatalities. NMSL was finally eliminated completely in 1995 with the passage of the National Highway System Designation Act. Shortly following repeal of the NMSL, many (although not all) states began increasing speed limits.

The repeal of the NMSL affected many more roadways than did the earlier change to 65 mph on rural Interstates, including urban Interstates and some non-Interstate highways. Currently, speed limits in Utah are 65 mph on urban Interstates, 70 or 75 mph on rural Interstates, and 65 mph on certain stretches of uncontrolled access rural two-lane roads. Timing of the speed limit change in Utah varied according to road type; for urban Interstates it occurred predominantly in December 1995, for rural Interstates in the last half of May 1996, and for rural two-lane roads it was spread across calendar year 1997.

NMSL repeal had no discernable impact on overall national rates of crashes and crash-related fatalities, which have been exhibiting a progressive decline for many years; this pattern was unaffected by NMSL repeal. Although some preliminary studies suggested that the increase in speed limits might have been associated with increase in crashes and fatalities on the affected roadways, particularly rural Interstates, they are not conclusive. National statistics on crash and fatality rates show no effect but are not specific for road type and posted speed limit. The current study was funded to investigate the changes in crash rates and fatal crash rates on those specific highways undergoing increase in speed limit.

Data were obtained from the Utah Department of Transportation describing traffic volume and speed limit. These files were manually combined to yield a file containing both traffic volume and speed limit data for every roadway segment of interest. Then, crash data were linked with hospital inpatient discharge data using probabilistic methodology. This linked file was combined with the traffic volume/speed limit file to yield a single file with one record for every crash. Information available in this file for each crash includes location, date, speed limit, severity, directional characteristics of the crash, whether the crash linked to the hospital discharge file, and if so, the dollar amount of hospital charges associated with the crash.

Analyses were conducted for both Interstate highways and state highways, separately according to posted speed limit. For Interstate highways, two types of road segments were identified: Rural segments, with current speed limits of 70 or 75 mph (all of these had speed limits of 65 mph prior to NMSL repeal); and urban segments with current speed limits of 60 or 65 mph (most but not all of these segments had 55 mph speed limit prior to NMSL repeal). For state highways, three types of road segments were identified: Low-speed segments, with current speed limits of 50 mph or less (these segments were unaffected by NMSL repeal and of minimal interest for this study; segments with speed limits of 55 mph (these

segments had 55 mph speed limits before NMSL repeal as well); and high-speed rural segments with current speed limit of 60 or 65 mph (speed limit on these segments was increased from 55 mph subsequent to NMSL repeal).

Statistical analysis was done to test for significant effects on crash rates, using autoregressive integrative moving average (ARIMA) intervention time series analysis. Analysis using annual crash rates resulted in too few observations to construct an ARIMA model, therefore monthly rates were calculated and used for this purpose. This statistical approach has previously been described for analysis of the effects of speed limit change on crash occurrence and is considered valid for this purpose.

Interstate Highways

Total annual traffic volume on rural Interstate segments increased from 2400 to 3600 million vehicle miles traveled (MVMT) from 1991-1999, an annual increase of roughly 5% and an aggregate increase of 52% during the study period. Total annual traffic volume on rural interstates increased from 3300 to 4400 MVMT from 1991-1999, roughly 3% per year and an aggregate increase of 32%. However, there was actually a slight year-to-year decrease in MVMT for urban Interstates for 1996-1997 and 1997-1998. This drop was likely related to the urban Interstate reconstruction project that began in 1996 in Salt Lake County, which is the largest urban area in the State and contains nearly 1/2 of the total urban Interstate mileage in the State. This was known as the “I-15 reconstruction project” but in fact had a major impact on all Interstate highways in the county.

Total crash number on rural Interstates increased from 1749 to 2260 from 1992-1999, while total crash rates displayed considerable year-to-year variability over the study period, but overall showed a decrease from 69.9 to 62.3 per 100 MVMT over the same period. Total crash number on urban Interstates showed a different pattern, with 3535 seen in 1992, followed by moderate year-to-year increases until 1996, when an upward “spike” to 6454 was seen, followed by a gradual decline in subsequent years (4570 in 1999). Total crash rates on urban Interstate showed a similar pattern, with an overall increase from 99.4 to 106.3 per 100 MVMT in 1992-1999, but with a “spike” to 147.2 per 100 MVMT in 1996. Analysis showed a statistically significant increase in total crash rates on urban Interstates associated with the increase in posted speed limits; there was no significant effect on total crashes on rural Interstates. The increase in total urban crash rates cannot be confidently attributed to the increase in speed limits, however; it may be confounded by the I-15 reconstruction project in Salt Lake County Interstate ongoing during the study period.

Annual fatal crash numbers on urban Interstates ranged from 19 in 1992 to 34 in 1999, while fatal crash rates ranged from 0.53 –0.77 per 100 MVMT over the same time period. Annual fatal crash numbers on rural Interstates ranged from 41-70 from 1992-1999, while fatal crash rates ranged from 2.4 -1.93 per 100 MVMT over the same time period. Fatal crashes comprised 0.5-0.7% of all crashes on urban Interstate segments and 2.3-3.1% of all crashes on rural segments. There were no apparent trends in fatal crash rates, or proportion of crashes that were fatal over the study period. Statistical analysis showed no significant effect on rates of fatality crashes associated with speed limit increase for either urban or rural Interstate highway segments.

Annual injury crash numbers on urban Interstates ranged from 581 in 1992 to 585 in 1999, with an upward “spike” to 840 in 1996. Annual injury crash rates on urban Interstates ranged from 16.3 – 13.31 per 100 MVMT over the same time period, with an upward “spike” to 19.16 in 1996. As noted above in the description of total crash number, the injury crash figures for 1996 were presumably affected by the I-15 reconstruction project in urban Salt Lake County. Annual injury crash numbers on rural Interstates ranged from 437 – 610 during 1992-1999, while injury crash rates ranged from 17.46 – 16.81 per 100 MVMT over the same time period. Injury crashes comprised 12.1-16.4 % of all crashes on urban

Interstate segments and 25.0-28.8% of all crashes on rural segments. There were no apparent trends in injury crash rates, or proportion of crashes that were associated with injury over the study period for rural Interstate segments. Statistical analysis showed no significant effect on injury crash rates associated with speed limit increase for either urban or rural Interstate highway segments, despite the apparent "spike" for urban Interstate segments.

Linkage (using probabilistic linkage methodology) of the crash file to the hospital discharge file was done to determine the number of hospitalizations that could be linked to crash records and to determine the hospital charges associated with each linked record. The likelihood of linkage (that is, the likelihood that a given crash can be associated with a hospitalization), and the dollar amount associated with each linked record, are reasonable proxies for crash severity. The total number of annual links for 1992-1998 ranged from 91-106 for urban Interstate segments, and from 85-151 for rural segments. The number of links per crash for the same time period ranged from 0.018 – 0.030 for urban Interstate segments and from 0.036 – 0.075 for rural segments. For both types of Interstate segments, there was considerable year-to-year variability for both the annual number of links and the number of links per crash. However, the number of links per crash in the last year of the period, 1998, was the lowest seen in the study period for both urban and rural Interstate segments. No trends or patterns could be discerned from the data, and there was no overall effect on crash-associated hospitalizations associated with speed limit increase.

Total annual inpatient charges for hospital records that could be linked to Interstate crashes varied from $1.8 – 3.2 million during 1992-1998, with the mean charges per linked record varying from $10,130 – 13,314 for the same time period. This analysis was done for all Interstate crashes combined. There was considerable year-to-year variation in both these variables, and no trend, pattern or effect of speed limit increase was seen.

State Highways

Only selected State highways were analyzed. Highways were chosen for analysis if they contained any segment on which the speed limit was increased as a result of NMSL repeal; in effect, this meant any highway containing a segment with current speed limit of 60 or 65 mph. Total mileage of segments affected by NMSL repeal –related changes in speed limit on State highways was 1718, actually somewhat greater than the affected mileage for Interstate highways. As noted above, highway segments were grouped into low-speed (current speed limit ≤ 50 mph), 55 mph (current speed limit 55 mph), and high-speed (current speed limit 60 or 65 mph) for purposes of analysis.

Total annual traffic volume on State highway segments chosen for study increased progressively during the study period, 1991-1999. Traffic volume increased from 10.85 to 15.51 100 MVMT for low-speed segments, from 4.94 to 7.47 100 MVMT for 55 mph segments, and from 11.23 to 18.66 100 MVMT for high-speed segments, an approximate annual increase of 1.4%, 1.5 %, and 1.7 % respectively for the three segment types.

Annual total crash number on low-speed segments showed a progressive increase from 5309 in 1991 to 7051 in 1991, while annual crash rates was approximately 500 per 100 MVMT, showing year-to-year variability but no overall trend. Annual total crash number on 55 mph segments was roughly 1200 for each year, showing year-to-year variability but no overall trend, while annual total crash rates on these segments showed a slow decline over time, from 249 per 100 MVMT in 1991 to 157.5 per 100 MVMT in 1999. Annual total crash number on high-speed segments showed a slow progressive increase from 1952 in 1991 to 2246 in 1991, while annual total crash rates on these segments showed a slow decline over time, from 177 per 100 MVMT in 1991 to 127 per 100 MVMT in 1999. Statistical analysis of the crash rates showed no significant effect on total crash rates associated with speed limit increase for high-speed segments.

Annual fatal crash number on low-speed segments ranged from 20 – 37 during 1991-1999, while annual fatal crash rates on these segments ranged from 1.33 to 3.13 per 100 MVMT; both fatal crash number and fatal crash rates showed year-to-year variability but no overall trend over the time period. Annual fatal crash number on 55 mph segments ranged from 6 – 23 during 1991-1999, while annual fatal crash rates varied from 1.21 to 3.39 per 100 MVMT; both fatal crash number and fatal crash rates showed year-to-year variability but no overall trend over the time period on these rural segments. Annual fatal crash number on high speed segments ranged showed much year-to-year variability, ranging from 41-86, while annual fatal crash rates on these segments ranged from 3.65 – 5.24 per 100 MVMT; for both fatal crash number and fatal crash rates the largest values occurred in 1997 and 1998, the year of speed limit change and the year immediately following the posting of increased speed limits. The proportion of all crashes associated with a fatality varied from 0.33-0.64% for low speed, 0.49-2.13% for rural segments, and 2.1-3.76% for high-speed segments during 1991-1999. Statistical analysis showed a significant increase in the rates of fatality crashes for high-speed segments of non-Interstate highway associated with the increase in posted speed limit. The proportion of crashes associated with a fatality also appeared to increase for high-speed segments in association with speed limit increase.

Annual injury crash number on low-speed segments ranged from 967 - 1137 during 1991-1999, while annual injury crash rates on these segments ranged from 84.2 in 1991 to 70.6 per 100 MVMT in 1999. Annual injury crash number on rural segments ranged from 222-250 during 1991-1999, while annual injury crash rates on these segments ranged from 44.7 in 1991 to 30.1 per 100 MVMT in 1999. Annual injury crash number on high speed segments ranged from 348-475 during 1991-1999, while annual injury crash rates on these segments ranged from 23.4-27.7 per 100 MVMT; the highest value, 27.7, was seen in the year of speed limit change, 1997, while the lowest value, 23.4, was seen in the last year of the study period. The proportion of all crashes associated with an injury varied from 15-18% for low-speed, 18-21% for 55 mph segments, and 18-21% for high-speed segments during 1991-1999. No trend over time was discernable in injury crash rates for any segment type, and the value for high-speed segments did not show any effect temporally associated with speed limit change during 1997. Statistical analysis showed no significant effect on injury crash rates on high-speed segments associated with speed limit increase.

Crash data files were linked with hospital discharge data files using probabilistic linkage methodology to provide information about hospitalizations and hospital charges associated with crashes. Annual number of links (the number of hospital inpatient records that could be associated with a crash), the number of links per crash, and the mean hospital charges per link (charges per crash-associated hospitalization) were calculated. Annual number of links for low-speed segments varied from 84-154 during 1992-1998, while the number of links per crash varied from 0.018-0.025; there was year-to-year variation for both variables but the lowest values for both were seen in the last year, 1998. Annual number of links for 55 mph segments varied from 27-61 during 1992-1998, while the number of links per crash varied from 0.025-0.051; there was year-to-year variation for both variables but the lowest values for both were seen in the last year, 1998. Annual number of links for high-speed segments varied from 59-139 during 1992-1998, while the number of links per crash varied from 0.025-0.063; there was year-to-year variation for both variables but the lowest values for both were seen in the last year, 1998. Annual mean hospital charges per linked hospitalization varied widely for all three types of non-Interstate highway segments, from $3133-11,249 for low speed segments, from $5529-15,812 for 55 mph segments, and from $8427-23,166 for high-speed segments. No trend over time was apparent for any segment type for any variable. No effect temporally associated with speed limit change could be seen for high-speed segments.

Conclusion

The results of this study provide information on crashes and crash severity in the context of changing speed limits over time, associated with NMSL repeal. The study was constructed to discover changes in crash occurrence and severity occurring in temporal association with speed limit change, on both Interstate highways and uncontrolled access State roads. We found a significant increase in total crash rates on urban (60-65-mph) urban Interstate highways, and a significant increase in fatal crash rates, and the proportion of crashes associated with a fatality, on high-speed (60-65-mph) rural non-Interstate segments. The following variable were unaffected: Total, fatality, and injury crash rates on rural Interstates segments; fatality and injury crash rates on urban Interstate segments; total and injury crash rates on high-speed non-Interstate segments; rates of linkage of crash files to hospital inpatient files, (reflecting the likelihood of a crash being associated with a hospitalization); and total and per-crash hospital inpatient charges.

The following concluding statements are offered:

- **No definitive statement can be made concerning the global impact of increased speed limits on crash occurrence or severity.**

- **Further analysis of speed limits vis-à-vis crash occurrence should be done at a regional rather than a state level.**

- **The effect of a change in speed limit as a single intervention on crash occurrence is difficult to detect.**

- **Further research aimed at reducing the occurrence and severity of motor vehicle crashes should not be narrowly focused on speed limits**.

- **Blanket alteration in speed limits imposed at the National level as a method of reducing crash rates or associated fatalities and fatalities cannot be supported by this study.**

The causation of motor vehicle crashes is complex, and speed limit only one of myriad operant factors, including roadway construction, weather and visibility, mechanical features of the vehicles, and various human factors including alcohol consumption. Although it seems intuitively obvious that higher travel speed might make crashes more likely and severe, the results of this study suggest changes in speed limit, at least in the range studied here, are not very powerful real-world influences on crash occurrence.

INTRODUCTION

The National Maximum Speed Limit (NMSL) originated in 1973, when an oil embargo in the Middle East resulted in serious shortages of fuels in the United States. The NMSL was one of several national energy-saving measures introduced at that time, and was designed to reduce fuel consumption by reducing typical vehicle travel speeds. It was initially 55 miles per hour (mph) nationwide. In the year following the enactment of the NMSL, the number of traffic fatalities decreased nationwide, from 54,000 in 1973 to 45,000 in 1974. (1) This decrease was attributed to the decrease in speed limits, and in response, Congress passed Public Law 93-643, making the change in national speed limits permanent. Therefore, a measure initially intended to promote fuel conservation was subsequently made permanent law as a public safety measure. In the following years, a number of studies were conducted evaluating the effect of the 55 mph NMSL, generally concluding that the NMSL resulted in significant decreases in traffic fatalities, and the concept that lowered speed limits reduce fatal crashes came into general acceptance. (1-3)

Over the next several years, political support for the NMSL gradually weakened for a variety of reasons, including the cessation of the fuel shortage, recognition that a large proportion of drivers were exceeding the posted 55 mph limit, and issues about state's rights to set speed limits within their own borders. Consequently, in 1987, the NMSL was altered when Congress passed the Surface Transportation and Uniform Relocation Assistance Act, which granted to States the authority to raise the speed limit to as high as 65 mph on certain rural Interstates. By 1988, roughly 90% of the eligible mileage of rural Interstates nationwide had speed limits of 65 mph. At this time, concerns arose, supported by a moderate amount of data, that the increase in speed limit might have resulted in higher numbers of crashes and fatalities. (4) The above noted opposition to a national speed limit continued, however, and the NMSL was finally eliminated completely in 1995 with the passage of the National Highway System Designation Act. Shortly following repeal of the NMSL, many (although not all) states began increasing speed limits.

The repeal of the NMSL affected many more roadways than did the earlier change to 65 mph on rural Interstates. As a result, speed limits have been increased not only on rural Interstates, generally to 75 mph, but also on urban Interstates (generally to 65 mph) and many stretches of uncontrolled-access non-Interstate highways (generally to 65 mph) as well. Once the NMSL was repealed, states were not uniform in their responses. For Interstate highways, 11 states raised speed limits soon after NMSL repeal, either late in 1995 or early in 1996, 21 raised speed limits later in 1996, and 19 states had made no changes in speed limits by the end of 1996. In Utah, speed limits were increased in several stages. Changes in posted speed limits on urban Interstates from 55 mph to 65 mph (a small stretch remained at 60 mph) occurred mostly in December 1995, and posting changes on rural Interstates from 65 to 75 mph (roughly 6% of mileage was posted at 70 mph) occurred mostly in May 1996; small stretches of both types of Interstates were posted at other times. Posted speed limits were increased from 55 to 60 or 65 mph on eligible segments of rural 2-lane State highways at various dates mostly during 1997.

Influence of Vehicle Speed on Crash Frequency

It is intuitive that increased vehicle speed should make crashes more likely, and a variety of mechanisms for this may be postulated. For instance, higher speeds reduce maneuverability, make it more difficult to steer around curves or avoid obstacles in the roadway, increase stopping distances, and decrease time available for a driver to react to adverse or unanticipated events on the roadway. At sufficiently high speeds, physical limits of the vehicle or roadway may be exceeded (e.g., traction of tires on the road surface). Many of these considerations are magnified in adverse conditions, such as poor visibility or on wet or snowy roads. In actual, real-world crashes, the speed of vehicles immediately prior to crashes is seldom known with any accuracy, complicating analysis. The information that is available, however, does not necessarily show a direct relationship between vehicle speed and crash likelihood. Rather, the relationship between speed and crash likelihood is generally demonstrated via a U-shaped curve, where crash probability is lowest at the median speed of the traffic stream (irrespective of speed limit), and rising at speeds above and below the median speed. (5, 6) Thus, deviant speeds, both high and low, have been associated with higher crash risk, leading to the general conclusion that variability in speed between vehicles on the roadway is a more important factor contributing to crashes than is vehicle speed per se. (7-9) This concept is widely but not universally accepted. In particular, some workers have found a direct correlation between higher speed and higher crash risk, with no increase in crash risk at lower speeds but a progressive rise with increasing speed (10), in some cases exponentially (11); however, few slow-moving vehicles were observed in these studies, possibly confounding the results. Conversely, *speeding*, that is, exceeding the speed limit or driving at speeds too fast for conditions, has been reported as a major factor in a large percentage of crashes, particularly fatal crashes, according to a report released by the National Highway Traffic Safety Administration (NHTSA). (12) However, high vehicle speed may not have been the sole or even major contributing factor in these speeding-associated crashes and fatalities, since there were many confounding factors. Speeding was associated with alcohol consumption, young, male drivers, and failure to wear seat belts. (12)

In contrast to the uncertain relationship between speed and crash *likelihood*, the relationship between speed and crash *severity* is incontrovertible, and follows from basic laws of physics. The kinetic energy of an object in motion varies as the square of its speed, so that a vehicle at 60 mph possesses energy that is four times as great as that at 30 mph, or, an increase in speed from 50 to 65 mph increases kinetic energy by 69%. This energy must be dissipated in a crash, obviously increasing the amount of energy potentially transferred to vehicle occupants. This physical relationship appears to translate directly to the chance of injury and fatality in motor vehicle crashes. Early studies found that the severity of injury in crashes increased rapidly at speeds above 60 mph, and that the possibility of fatality increased rapidly as speeds exceeded 70 mph. (6) During a crash, the vehicle undergoes a change in speed as a result of impact, which may be all the way to rest (zero speed) but often is not. This change in speed, or delta-V (ΔV) is logically a better indicator of energy released, and potentially transferred to vehicle occupants, than is road speed immediately prior to the crash. Using this concept, it has been estimated that the possibility of fatal injury is proportionate to ΔV at impact raised to the fourth power. (13) According to this study, a crash yielding a ΔV of 50 mph was 15 times as likely to result in fatality as a crash with a ΔV of 25 mph. Also, it was found that the risk of death in a crash exceeded 50% when the change of speed at impact exceeded 60 mph. Comparison of studies across time suggests that the risk of injury or fatality for any given ΔV has decreased progressively over the years, possibly reflecting improved vehicle crashworthiness or increased seat belt use, although the exponential relationship between vehicle speed and injury severity appears to be maintained. (9, 13, 14)

Table 1. National trends in fatal and injury crash rates, 1990-2000.

	VMT Billions	Number Killed	Fatality Rates per 100 MVMT	Number Injured	Injury Rates per 100 MVMT
1990	2,144	44,599	2.1	3,231,000	151
1991	2,172	41,508	1.9	3,097,000	143
1992	2,247	39,250	1.7	3,070,000	137
1993	2,296	40,150	1.7	3,149,000	137
1994	2,358	40,716	1.7	3,266,000	139
1995	2,423	41,817	1.7	3,465,000	143
1996	2,486	42,065	1.7	3,483,000	140
1997	2,562	42,013	1.6	3,348,000	131
1998	2,632	41,501	1.6	3,192,000	121
1999	2,691	41,717	1.6	3,236,000	120
2000	2,693	41,821	1.6	3,189,000	118

100 MVMT = 100 million vehicle miles traveled
Adapted from "Traffic Safety Facts 2000 Overview, US DOT HS 809 329

Given that higher vehicle speeds are at least potentially associated with a greater probability of crashing, and clearly associated with increased crash and injury severity, what is the effect of higher *speed limits* on motor vehicle crashes, injuries, and fatalities? In the US, a sort of natural experiment has been conducted in this regard, as speed limits were reduced to 55 mph and then increased again in a stepwise fashion, first to 65 mph and then to as high as 75 mph with the repeal of NMSL. Unfortunately, reports of the effect of these speed limit changes on crashes and injuries must be viewed cautiously. For instance, logically crash occurrence should be proportional to exposure, that is, the number of miles driven. However, fatalities and crashes are often expressed not as rates per vehicle mile traveled but as number of crashes per year. It is worth noting that the initial enactment of NMSL as a safety measure appeared to be based on annual crash numbers rather than crash rates, neglecting the possibility that the fuel shortage and increased fuel prices extant in the early 1970s might have reduced traffic volume and miles driven. (In this report, the term "crash rates" should be taken to mean crashes per vehicle mile traveled.) Also importantly, any changes in crash rates are superimposed on a background of steadily decreasing crash and fatality rates over time, which has been ongoing in the US for as long as 75 years; crash, injury and fatality rates in 1999 and 2000 were at the lowest rates in US history (Table 1). (15) Therefore, a comparison of crash rates across time may not provide an accurate assessment of the effect of a change in speed limit. Instead, one would have to assess whether crash rates following any change in speed limit are different from would have been predicted based on trends before the change occurred.

A number of studies exist relating crashes, injuries, and fatalities to speed limits, from the US and Europe. (9) The studies of reductions in speed limits are mostly in agreement that, when speed limits are reduced, a decrease in crashes and fatalities is seen. The decrease in traffic fatalities seen after NMSL enactment was interpreted as showing such a cause-effect relationship. A study of an Illinois toll road found that rates of crashes and fatalities per vehicle mile were reduced following institution of the 55 mph speed limit in 1974. (16) This study was notable because the traffic volume was accurately measured; however, the reduction reported could be interpreted as merely the continuation of a downward trend that had been ongoing for several years prior to the speed limit change (*vide supra*).

A handful of published studies have examined the effect of the speed limit increase to 65 mph on rural Interstates in 1987, most reporting specifically on fatal crashes rather than total crashes or injury crashes. In studies of single states, crash-related fatalities were reported to have increased in most cases; the increment ranged from 18% in Alabama to 110% in Washington State. (17-22) Total crashes were reported to have increased in some but not all studies. (18, 19) A smaller number of studies found that speed limit increases did not lead to increases in crashes or fatal crashes. (8) In Alabama, Ohio, Indiana and Virginia, the increase to 65 mph speed limit could not be linked to any increase in crashes, fatal crashes, or both. (22-25)

Studies of the increase to 65 mph speed limit on rural Interstates using national crash data are less consistent in their findings. NHTSA released a study in which it was estimated that crash-related fatalities on rural Interstates in 1990 were 30% higher than would have been predicted had the speed limit not been increased. (4) Baum et al estimated that the change to 65 mph resulted in 15% more fatalities in the first year than if the states had maintained the 55 mph limit, and a 30% increment in the second year. (26, 27) It is worth noting, however, that the statistical method used did not appear to account reliably for increasing traffic volume. (27) Garber and Grahman, using data from the Fatality Analysis Reporting System (FARS),[1] made similar conclusions, although they noted that there was great variation from state to state and that some states showed no effect, or even fewer than predicted fatalities after the speed limit increase. (28) Balkin et al (29), also using FARS data, estimated that rural Interstate fatalities were higher than predicted in 19 of 40 States subsequent to the increase in rural Interstate speed limit from 55 to 65 in 1987. Other studies have failed to show a consistent increase in crashes or fatalities related to increased Interstate speed limits. One analysis of FARS data done early on after the increase to 65 mph, using a sophisticated time series analysis statistical technique, found no significant increase in crash fatalities nationwide. (30) Chang et al (25), studying fatal crashes, found an inconsistent effect of increased speed limit, reporting that fatality rates in large States such as Texas and California showed little effect, while smaller States did show increased fatality rates. Lave and Elias (31) reported that the increased speed limit on rural Interstates decreased nationwide fatality rates by 3.4% - 5.1%; in their analysis, they considered fatal crashes occurring on all highways (not just Interstates), reasoning that Interstate speed limit changes likely would affect traffic patterns on other highways as well. At least one study of non-Interstate highways also reported that increased speed limits led to decrease in crash occurrence (fatalities were not studied in this instance). (32).

At this point, there are only sparse data published for the more recent (and more global) increase in speed limits related to the complete repeal of NMSL. NHTSA has conducted a preliminary study, which was released in February of 1998. (1) The study compared calendar year 1995 to 1996, and was an analysis of both national data and of data from 10 states that submitted reports. The study found that nationally, there was no change in the total number (on all roadways) of fatalities or injuries between the two years. Specifically examining Interstate highways using a linear regression model, it was concluded that increased speed limits resulted in an increased number of fatalities occurring in Interstate crashes above that predicted based on historical trends. The excess in fatalities was estimated at 9%, or about 350 more Interstate fatalities nationally than predicted. Interstate crash fatality rates in states that did not change speed limits did not differ from predicted levels. It was further concluded that the number of injuries and injury crashes each increased by about 4%. In the Discussion section of this report, it was acknowledged that several types of data were not available, notably for traffic volume, traffic volume by roadway type, and medical costs. The report was judged to provide "…gross estimates of the potential impact, in terms of increases in fatalities and associated economic costs at the national level in states that increased speed limits…". (1) Further study of the issue was thought necessary, particularly in light of the lack of exposure (traffic volume) data.

Ten States also submitted individual reports in conjunction with the NHTSA report. (1) Although analyses from some States (California, Nebraska, several Midwestern States) appeared to mirror the national report, others (Idaho, Montana, Florida) reported no change or even a decrease in crash fatalities.

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[1] *The Fatality Analysis Reporting System (FARS) contains data on all fatal traffic crashes within the 50 states, the District of Columbia, and Puerto Rico. The data system was conceived, designed, and developed by the National Center for Statistics and Analysis (NCSA) to assist the traffic safety community in identifying traffic safety problems, developing and implementing vehicle and driver countermeasures, and evaluating motor vehicle safety standards and highway safety initiatives. Data on non-fatal crashes is not included. FARS data can be seen and queried on websites maintained by both NHTSA and NCSA.*

Of interest, the States were unanimous in stating that their studies did not allow them to make definitive conclusions about the effect of increased speed limit on Interstate highways.

One other national study of the effects of NMSL repeal is available. (29) Using FARS data, these workers estimated that after NMSL repeal and associated increase in speed limit on both urban and rural Interstates, 10 of 36 States experienced an increase in rural Interstate fatalities, and 6 of 31 experienced an increase in urban Interstate facilities. They did not describe events in the States that did not experience a decrease, and it is not clear whether the fatalities in those States did not change or actually decreased.

Limited data related crash occurrence to NMSL repeal are available from individual States. In Virginia, a study of an increase in rural Interstate speed limit to 70 mph found no increase in crash severity (crash rates was not assessed in this study). (33) In a more comprehensive study, Kansas reported no significant effect on crash or fatality rates on either urban or rural Interstates, when speed limits were increased to 70 and 65 mph respectively. (34) However, they did find a statistically significant increase in crashes and fatalities on rural 2-lane highways after the speed limit was increased to 65 mph.

It is important to note that the relationship between speed limit and typical vehicle speed is not straightforward. At first consideration, that vehicle speed on a given highway is directly related to (and controlled by) posted speed limit may seem a reasonable assumption. This assumption obviously underlies the entire concept of posting speed limits. However, real-world vehicle speed may not change very much when speed limits are altered. Evidence suggests that drivers typically choose travel speeds based largely on intuitive understanding of safe and reasonable speeds for prevailing road and weather conditions, etc, as well as the posted speed limits. There is reason to believe that drivers do so in a reasonable manner, choosing speeds that generally are appropriate for the roadways and conditions. In fact, traffic engineers rely on this principle when designating speed limits; optimum speed limit is generally considered to be at the 85^{th} percentile speed of free-traveling vehicles. (32, 35) Drivers may be unwilling to conform to speed limits that they perceive to be unreasonable for the highway and conditions. (35) Studies have generally reported increments in average vehicle speed considerably smaller than those in posted speed limit. (9, 19, 25, 32, 34, 35) In at least one study, changes either up or down in posted speed limit had no discernable effect on the actual vehicle speed. (32)

Although discussions of speed limit increases usually focus on the hazards possibly imposed, might there be some beneficial effects as well? Logically, any such benefits would seem related to reduced travel time, primarily stated as savings in time and secondarily, money. Some have reasoned that travel at higher speeds should reduce travel time, and therefore decrease in the time drivers spend on the road. Fewer hours driving may reduce the chance that drivers will become drowsy, possibly reducing the number of drowsiness-related crashes. Drowsiness is known to be a factor in causation of motor vehicle crashes, especially single-vehicle crashes on monotonous high speed roads. (9, 36-38) Crashes related to drowsiness are known to have certain characteristics, such as single-car leaving the road events and single-vehicle, single-occupant events; they also have a higher fatality and injury rates than crashes in general, amplifying their importance. (38) It can be reasoned, then, that single-vehicle crashes on rural Interstates have drowsiness as a major causative factor. If the increase in speed limit does indeed lead to a decrease in driver drowsiness -related crashes, then this may be reflected by a decrease in the proportion of crashes of those specific types.

Overall, then, the relationship of speed limits to motor vehicle crashes, injuries and fatalities is not straightforward. The causation of motor vehicle crashes and resultant injuries and fatalities is complex, and includes myriad factors such as alcohol, traffic density, road and weather conditions, driver experience and willingness to take risks, time of day, among many others. Although available evidence appears to suggest that higher speed limits lead to higher risks of crashes and injury, this evidence is by no means incontrovertible, and the issue has been vigorously contested by a number of groups as well as the automotive and general press. (39-41) Indeed, the repeal of the NMSL, and the subsequent increase in speed limits in many states, does not appear to have significantly interrupted the steady downward trend in motor vehicle crash-related mortality that has been occurring in the US over the past 75 years.

OBJECTIVES

The objectives of this project were to evaluate the effects of increased speed limits on aspects of motor vehicle crashes in the State of Utah, following the repeal of the National Maximum Speed Limit (NMSL) in 1995.

- To determine the effect of increased speed limits on the number and rates of crashes on Utah highways.
- To determine the effect of increased speed limit on the number and rates of fatal crashes in Utah.
- To determine the effect of increased speed limits on the number, severity, and economic impact of injuries experienced as a result of motor vehicle crashes in Utah adjusted for changes in traffic volume.
- To determine the effect of increased speed limits on the number of single-vehicle crashes in Utah.

METHODOLOGY

Datasets Available

This research was conducted by analysis of the following computerized datasets.

State of Utah Datasets

Crash File. The crash file is a compilation of police crash reports, containing data describing each crash including location, data and time, road speed limit, nature of the crash, alcohol involvement, etc. The structure of this file is complex, and it is actually composed of three separate files: a crash level file, a vehicle level file, and an occupant level file. Each of the roughly 50-60,000 crashes occurring yearly in Utah generates records in each of these files; one record in the crash level file, one or more in the vehicle level file (depending on the number of vehicles involved in the crash), and one or more in the occupant level file (one record for each occupant of every vehicle in the crash). The crash files are complete for every crash in the state of Utah for years 1992-1999. Also, the crash file has been linked (using probabilistic linkage methodology) to the hospital inpatient file for the years 1992-1998 (*vide infra*).

*Hospital inpatient fil*e. The hospital inpatient file is a compilation of hospital discharge files from the entire state of Utah. Information contained in this file includes demographic data, diagnosis codes, hospital charges, and patient outcome at discharge, for every patient who was discharged from a hospital in the state of Utah. This file is available and linked to the crash file for 1992-1998 (*vide supra*). There are about 220,000 records per year in this file.

Datasets from the Utah Department of Transportation (UDOT)

*UDOT Traffic Statistic*s. Data describing traffic volume are acquired at traffic recording stations throughout Utah. Data are reported as average annual daily traffic (AADT) (average number of vehicles per day) for road segments. For the purposes of measuring and reporting traffic volume, each road in the state is divided into a number of segments of varying length, typically of a few miles in length but ranging from less than 0.1 mile to as much as 80 miles. The number of segments for each road obviously varies with length and type of roadway, ranging from one segment to as many as 200. Data are reported monthly with yearly summaries. Eighty-one permanent recording stations were previously operating, however reconstruction occurring along certain urban Interstates in Salt Lake County eliminated some of these stations and affected data acquisition at others. There are also a variable number of temporary recording stations. The location of each station is precisely specified, providing specific measurement of changes in traffic volume at many points throughout the Utah road system. These data are freely available from UDOT (http://www.dot.state.ut.us/progdev/traffic). Estimates of vehicle miles traveled are also available from UDOT according to road ownership (federal, state, city, county). Road segments used for reporting traffic volume are defined differently from those used for speed limit definitions; starting and ending points, segment lengths, and number of segments per road are different in the two files.

UDOT Road File. This data set is a description of all current speed limits on roads maintained by UDOT, and specifies the speed limit for every location on Utah roads. For purposes of describing the speed limit, each road is divided into segments of varying length. Current speed limit and the date it became effective are reported for each segment. Segments vary in length from less than 0.1 mile to more than 60 miles, and the number of segments per road varies from one to more than 150. This file does not contain historical information, and has no data describing the speed limit for any road segment prior to the most recent change (such data are available only as paper records of engineering orders for altering the speed limit signage). The file is maintained as a word processing document and is not a searchable database. Road segments used for speed limit definitions are defined differently from those used for reporting traffic volume; starting and ending points, and segment lengths, and number of segments per road are different in the two files.

Creation of Dataset for Analysis

Selection of Roads for Analysis. Roads were selected for analysis of crash rates if they were affected by speed limit changes occurring after NMSL repeal. All Interstate highways were selected. State roads were selected if they included segments of road that were affected by the speed limit changes, that is, if they currently have segments with speed limits of 60 or 65 mph. Separate datasets were created for State roads and Interstate highways, and the two were analyzed separately.

Creation of linked crash and hospital file. Probabilistic linkage methodology was used to link data about individuals in crashes, from the crash file to the hospital discharge file.[2] Each such link identified an association between a record in the crash and one or more records in the hospital discharge file; that is, each link identified an individual who experienced a hospital stay as a result of the crash. Obviously, many crashes did not result in any hospitalization and therefore no link could be established between the crash and hospital discharge file in such cases. In other cases, there might be several injured persons requiring hospitalization from the vehicles involved in the crash, resulting in several links between the two datasets. The result of the linkage procedure was a dataset that contained one record for each crash. Each record noted the number of links of the hospital record with each crash, from zero to many. In addition, for each crash record it was noted the total hospital charges from all hospital records that linked to the crash record.

Creation of VMT file. Separate files were created for Interstate and State Highways. Traffic statistics from relevant years 1991 – 1999 were combined into one large dataset which contained AADT for each road segment for all years. AADT was converted to traffic volume, expressed as 100 million vehicle miles traveled annually (100 MVMT) for each segment according to the following formula:

$$100\ MVMT = \frac{AADT \times sectionlength \times 365}{10^8}$$

Then, speed limit for each road segment was added to the file. Because road segments for the traffic volume and for speed limit designation are defined differently, extensive analysis of the two datasets was necessary. Result of this process was the creation of a dataset that specified both speed limit and annual traffic volume by year for every segment of highway.

2 Probabilistic linkage is an iterative tool that is used to link records from disparate databases, to associate records containing data related to discrete events. It able to overcome the inaccuracies and errors which characterize real-world databases, (e.g., incorrect, missing or duplicate data, typographical errors, changes in surnames, etc.), which would foil exact matching strategies. Probabilistic linkage is amply described elsewhere. (42, 43) Data linkages were performed using Automatch Software®.

Creation of final dataset for analysis. The two datasets created as described above were then combined in a join operation. The result of this operation was a database containing one record for every crash, specifying the road, location, speed limit, number of links of the crash record with the hospital file, and other characteristics of the crash. Separate datasets were created for Interstate and State highways. Database structure is listed in Table 2.

Table 2. Database file structure.

Variable name	Description
routenum	Road number
begpoint	Milepoint of segment start
endpoint	Milepoint of segment end
length	Segment length
location	Text description of segment location
aadt	Annual average daily traffic for segment
splim	Speed limit at crash point
dateposted	Date at which speed limit was posted
year	Year of crash
accnum	Crash number (sequential)

Variable name	Description
milepnt	Milepoint of crash
accdate	Crash date
severity	Injury severity as assessed by police
acctype	Type of crash
light	Lighting conditions at time of crash
diranlys	Direction of travel of vehicles involved
numinpat	Number of links of crash record to hospital file
sumcharges	Total inpatient charges associated with crash
accmonth	Month of crash

For purposes of analysis, all segments of Interstate highway were classified as either rural or urban according to speed limit currently assigned. For Interstate highways, segments of highway with a current (post- NMSL repeal) speed limit of 60 or 65 mph were designated “urban”, while segments with a speed limit of 70 or 75 mph were designated “rural”. This designation is reasonable for Interstate highways, since speed limits are assigned largely according to population density and traffic pattern.

For non-Interstate roads, rural/urban designation was not logical, since speed limits are determined based on a variety of factors in addition to population density, such as road width and condition, curves, grade, line of sight, etc. Therefore, roadway segments were aggregated into 3 types: “Low-speed”, “ 55 mph”, and “high-speed”. Low-speed designation was given segments with a current speed limit of 50 mph or less. It was recognized that this designation was assigned to segments with wildly varying characteristics, from small-town “main streets” to secondary rural highways through sparsely populated frontier areas of Utah. However, speed limits on such road segments were not affected by NMSL repeal and thus these segments are of limited interest in the context of this study. 55 mph designation was given segments with current speed limit of 55 mph. Although speed limits on these segments would not have been affected by NMSL repeal, these were rural highways that could be usefully compared to segments where the speed limit was increased. High-speed designation was given segments with a current speed limit of 60 or 65 mph. These were the only non-Interstate highway segments directly affected by NMSL repeal, since speed limits higher than 55 mph on uncontrolled access highways did not exist prior to repeal. High-speed segments were obviously of the greatest interest in the present study.

Aggregation of roadway segments into the groups described above was necessary for data analysis. Although it might seem interesting to have detailed data by specific highway or segment of highway, the numbers of crashes (and particularly, fatal crashes) were small for any such division of roadway, making meaningful analysis difficult.

Statistical Analysis

Data were analyzed for the effect of speed limit increase using autoregressive integrative moving average (ARIMA) intervention time series analysis. A thorough treatment of ARIMA can be found elsewhere. (44) Intervention time series analysis is a modification of the Box-Jenkins (ARIMA) procedure (44) and is designed to test for the effect of an outside intervention (in this case, an increase in posted speed limit) on a series of data across time (in this case, periodic measurements of crash rates). It takes into consideration properties of the data such as trends across time (such as the ongoing decrease in crash rates in the US) and seasonality (sometimes seen in motor vehicle crash data). In this analysis technique, the statistical model is not arbitrarily imposed on the data but is built empirically for each data series analyzed. The first step in an intervention time series analysis is to identify a model that fits the portion of the data from before the intervention. Model identification follows a three stage iterative procedure: identification, estimation, and diagnosis. To achieve a stationary time series it was sometimes necessary to use differencing and square root transformations. Once a model is identified an intervention function is determined and the model is applied to the entire time series, before and after the intervention. In all models it was assumed that the change in speed limit had an immediate and constant effect on crashes during the study period. This statistical method has been previously used and is regarded as appropriate for the analysis of the effect of speed limit changes on crash occurrence; ample descriptions are available elsewhere. (17, 18, 25, 30, 45, 46) A p value of .05 was considered significant.

RESULTS

Preliminary Utah Results

Crash data for the state of Utah for the years 1970-1999 are shown in Table 3 below. Similar to national trends, there is a progressive decline in fatal crash rates over the entire time period. As for the nation as a whole, crash fatality rates in Utah are now at the lowest rates in history. There is a parallel although less pronounced decline in total crash rates and crash injury rates over the same time period. These data are presented graphically in Figures 1 and 2 on the next page. These analyses have been produced annually for some time but detailed analyses by speed limit and type of road have not been available.

Table 3. Annual occurrence and rates of total crashes, fatality crashes, and injury crashes for Utah, 1970-1999

Year	Million Vehicle Miles Traveled (MVMT)	Total Crashes	Injury Crashes	Fatal Crashes	Total Crash Rates per 100 MVMT	Injury Crash Rates Per 100 MVMT	Fatal Crash Rates per 100 MVMT
1970	6108	35166	10722	276	575.7	175.5	4.5
1971	6544	39108	11399	280	597.6	174.2	4.3
1972	6969	39856	11630	312	571.9	166.9	4.5
1973	7274	38234	11710	304	525.6	161.0	4.2
1974	7457	31401	10560	204	421.1	141.6	2.7
1975	7942	36426	11441	245	458.7	144.1	3.1
1976	8420	34345	11685	225	407.9	138.8	2.7
1977	9054	38524	12652	310	425.5	139.7	3.4
1978	9826	42684	13423	315	434.4	136.6	3.2
1979	9811	40468	13449	287	412.5	137.1	2.9
1980	10645	33582	11701	292	315.5	109.9	2.7
1981	10733	35989	11824	321	335.3	110.2	3.0
1982	10947	38192	11504	263	348.9	105.1	2.4
1983	11228	40989	12317	253	365.1	109.7	2.3
1984	11642	47489	13477	274	407.9	115.8	2.4
1985	12035	47871	13917	270	397.8	115.6	2.2
1986	12253	46690	13988	276	381.0	114.2	2.3
1987	12679	47256	13599	271	372.7	107.3	2.1
1988	13263	49249	13377	258	371.3	100.9	1.9
1989	13915	51320	13941	269	368.8	100.2	1.9
1990	14646	52691	14632	236	359.8	99.9	1.6
1991	15390	47435	13763	229	308.2	89.4	1.5
1992	16263	50660	15665	235	311.5	96.3	1.4
1993	17055	55704	17088	259	326.6	100.2	1.5
1994	18080	59272	18726	303	327.8	103.6	1.7
1995	18786	57644	19828	284	306.8	105.5	1.5
1996	19433	61505	20988	292	316.5	108.0	1.5
1997	20408	54952	21131	309	269.3	103.5	1.5
1998	21237	54072	19427	308	254.6	91.5	1.5
1999	21867	52802	19513	318	241.5	89.2	1.5

Figure 1. Fatal crash rates on all Utah roadways, 1970-2000.

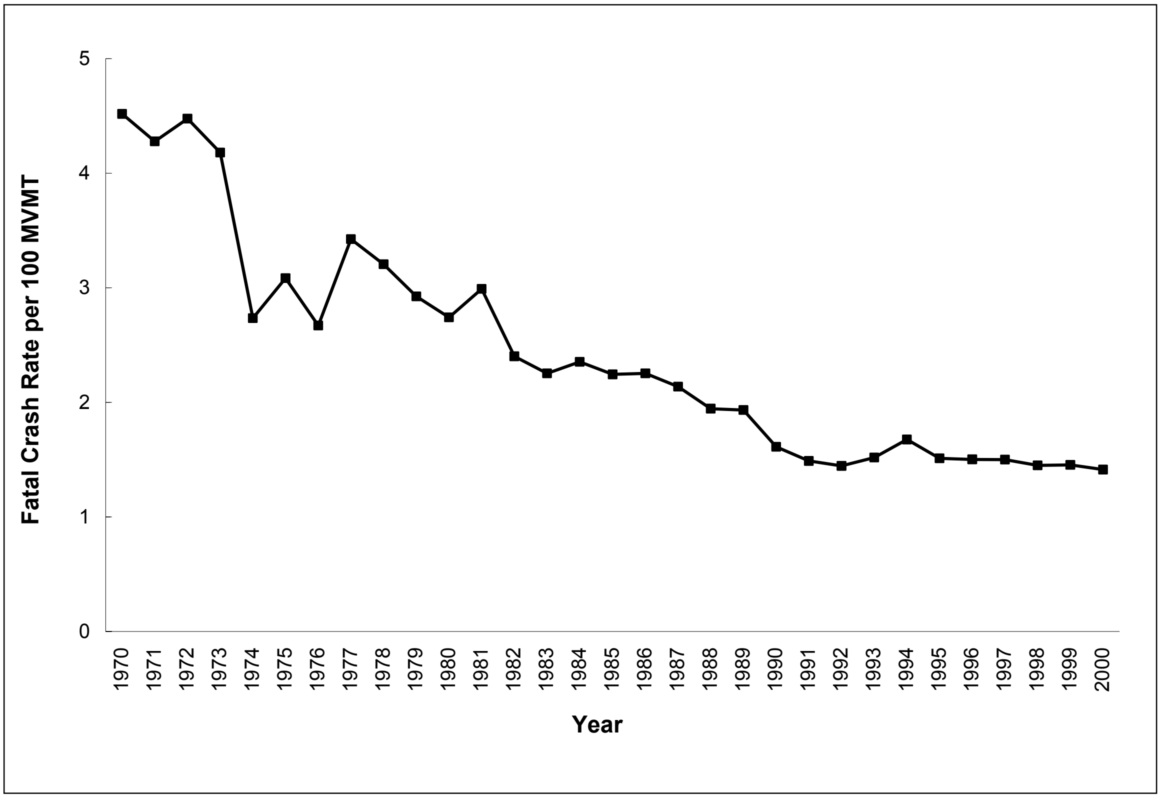
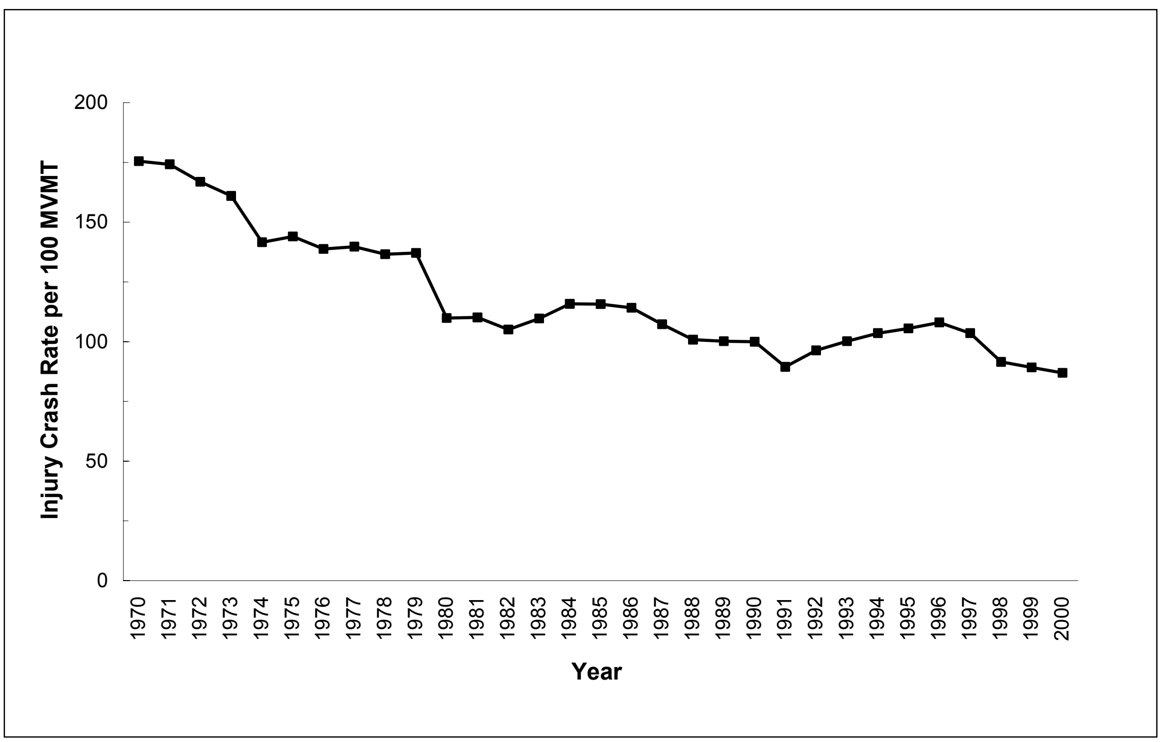


Figure 2. Injury crash rates on all Utah roadways, 1970-2000.



Interstate Highways

All analysis of crashes on Interstate Highways was done after aggregating roadway segments into rural and urban types. Urban segments were identified by current speed limits of 60 or 65 mph, and rural segments by speed limits of 70 or 75 mph. The majority of Utah's Interstate system is rural in nature. Urban segments lie in the State's population concentration, a north-south corridor roughly 80 miles in length, centered around Salt Lake City, the State's largest city, and extending from Provo in the south to Ogden in the north. I-15 runs essentially through the center of this corridor. Although it might seem interesting to have detailed data by specific Interstate or even segment of Interstate, the numbers of crashes (and particularly, fatal crashes) were small for any such division of roadway, making meaningful analysis difficult.

Table 4. Current speed limits on Utah Interstate highways, mileage by route number.

Route number	Current Speed Limit, mph	Mileage
I-215	65	29.0
I-215 Total		29.0
I-15	65	95.5
	75	443.8
I-15 Total		539.2
I-70	60	8.6
	70	25.9
	75	210.5
I-70 Total		245.0
I-80	65	46.6
	70	23.1
	75	137.6
I-80 Total		207.3
I-84	65	39.5
	75	43.2
I-84 Total		82.7
Grand Total		1103.3
60-65 mph Total		219.2
70-75 mph Total		884.1

All Interstate highways were analyzed for crash rates. Breakdown of mileage and current speed limit by route are noted in Table 4. I-215 is a belt route located in metropolitan Salt Lake City, and is exclusively urban in character. I-15 is the major north-south route in the state, extending from the southeast corner of the state to the northern border with Idaho. It is largely rural except for the portion that runs through the urbanized part of Utah, roughly between the cities of Provo and Ogden. I-70 runs east to west, from its intersection with I-15 to the eastern border with Colorado, it is almost entirely rural. Interstate 80 is the major east-west route, passing through central Salt Lake City but otherwise rural in nature. Interstate 84 runs in a SE-NW direction through northern Utah, and is both rural and urban in nature.

Breakdown of mileage, speed limits, and dates posted are noted in Table 5. It can be seen that the change in posted speed limit on rural Interstate routes from 65 to 70 or 75 mph occurred more or less simultaneously in mid-to-late May, 1996, about 5 months after NMSL repeal formally took place; except that a 43.2 mile segment of I-84 was changed to 75 mph in mid-November of that year. For urban routes, posting of speed limit increase from 55 to 60 or 65 mph was done primarily in December 1995, earlier than for rural segments. Roughly 70% of the mileage was posted at that time, the remainder had mostly been posted at 65 mph before NMSL repeal, but underwent no change after repeal.

Table 5. Speed limits on Utah Interstate highways, mileage and date speed limit posted.
Current and pre- repeal of the National Maximum Speed Limit Law (NMSL).

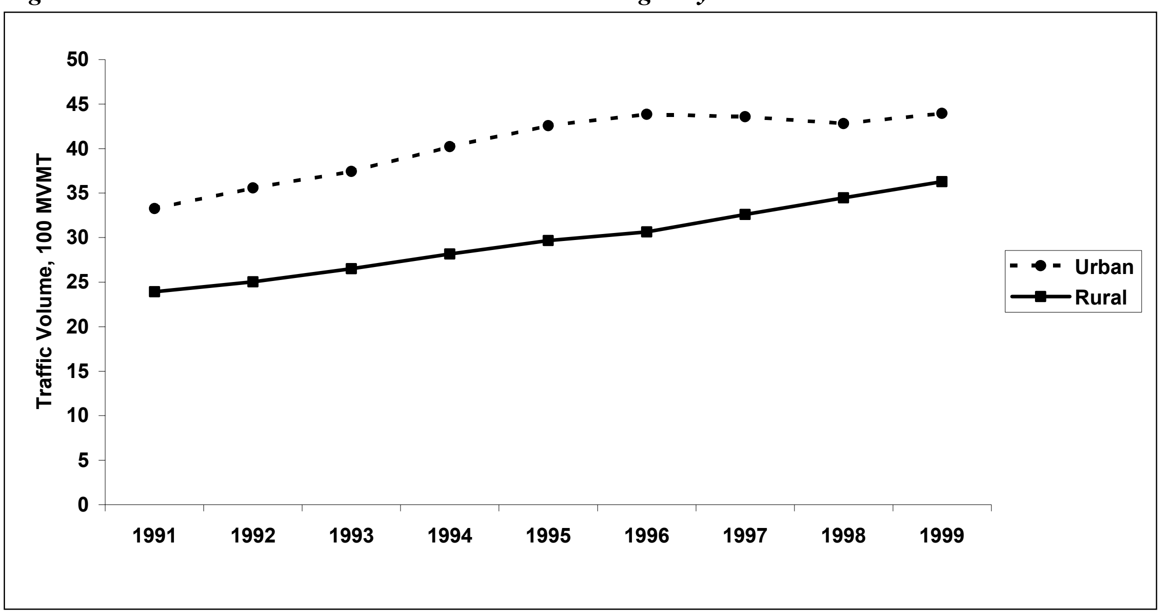
Current	Pre-NMSL Repeal	Date Posted	Mileage
60	55	5/21/1987	8.6
60 total			8.6
65	55	5/21/1987	46.3
		2/27/1993	2.4
		10/15/1993	9.3
		12/19/1995	149.9
		12/4/1997	2.8
65 total			210.6
70	65	5/16/1996	23.1
		5/31/1996	25.9
70 total			49.0
75	65	5/16/1996	192.7
		5/22/1996	388.7
		5/30/1996	210.5
		11/19/1996	43.2
75 total			835.1
Urban (60-65 mph) total			219.2
Rural (70-75 mph) total			884.1

Table 6. Vehicle miles traveled on all Utah Interstate Highways, 1991 – 1999.

	Urban		Rural	
	100 MVMT	Change from previous year	100 MVMT	Change from previous year
1991	33.3		23.9	
1992	35.6	6.9%	25.0	4.7%
1993	37.4	5.2%	26.5	5.9%
1994	40.2	7.4%	28.1	6.2%
1995	42.6	5.9%	29.7	5.4%
1996	43.8	3.0%	30.7	3.3%
1997	43.6	-0.6%	32.6	6.3%
1998	42.8	-1.8%	34.5	5.8%
1999	43.9	2.7%	36.3	5.2%
Total change		32.1%		51.7%

During calendar years 1991-1999, there was a progressive increase in traffic volume on Utah Interstate Highways (Table 6, Figure 3). This was true for both urban and rural Interstate segments, but there were some differences in the pattern seen between them. Rural segments showed a steady and nearly linear increase of roughly 5% per year, and a total increase of about 50% over the 9-year period. Urban segments showed a similar increase for 1991-1995, but a smaller increase for 1996 and actual decreases in 1997 and 1998 compared with previous years. This can be explained by the major I-15 reconstruction project that was ongoing in Salt Lake County beginning in April 1996 and extending through the rest of the study period. Salt Lake County contains Salt Lake City and is the largest metropolitan area in the State, and thus contains a large part of the State's urban Interstate mileage, both on I-215, the urban belt route (29 miles) and on the urban portions of I-15 (26.5 miles) and I-80 (40.6 miles). Of the total of 211 miles of urban Interstate in Utah, 96 miles (about 46%) are in Salt Lake County. Although the project was termed the "I-15 reconstruction project", it had a major effect on all Interstate mileage in Salt Lake County. During the reconstruction project, traffic patterns on these urban Interstate segments were disrupted, with diversions and closures of parts of both I-15 and I-80 for periods of up to several years. Thus, the reconstruction project seems an obvious cause of the discrepancy between the traffic growth between the urban and rural Interstate segments.

Figure 3. Vehicle miles traveled on all Utah Interstate Highways



Total Crashes on Utah Interstates

Table 7 and Figures 4 and 5 show crash number and rates on Utah Interstates by year and roadway type.

Total crash number on rural segments showed a general upward trend over time, with year-to-year variability. Urban segments showed a discernable increase or spike in total crash number in 1996, with a subsequent decrease in total crash number in ensuing years.

Total crash rates on rural (70-75 mph) segments showed a progressive decrease of about 1% per year overall. Intervention time series analysis showed there was no significant effect on total crash rates on rural segments temporally associated with the increase in posted speed limit (p = .374).

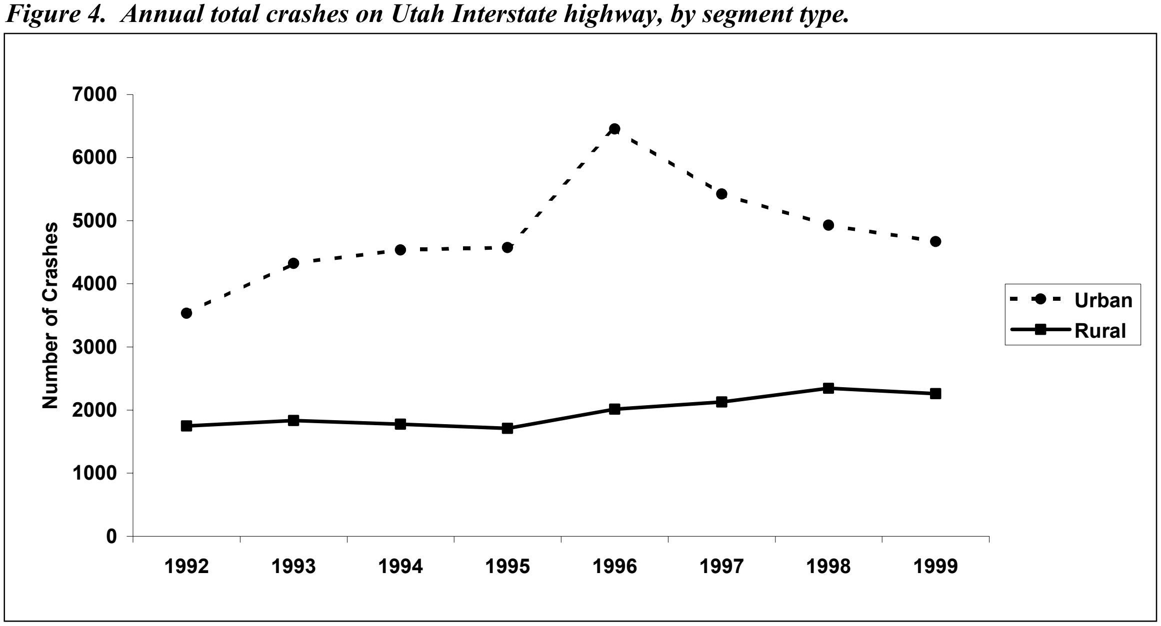
Urban segments showed a "spike" in total crash rates in 1996, as they did for total crash number, with decreases in subsequent years. Intervention time series analysis showed a significant increase in total crash rates on rural segments temporally associated with the increase in posted speed limit (p = .039).

Table 7. Annual total crashes and crash rates on Utah Interstate highways by segment type.

		1992	1993	1994	1995	1996	1997	1998	1999
Urban	Crashes	3535	4322	4539	4573	6454	5424	4932	4670
	Crash Rates per 100 MVMT	99.4	115.5	112.9	107.4	147.2	124.4	115.2	106.3
Rural	Crashes	1749	1833	1778	1708	2013	2126	2343	2260
	Crash Rates per 100 MVMT	69.9	69.2	63.2	57.6	65.7	65.2	68.0	62.3

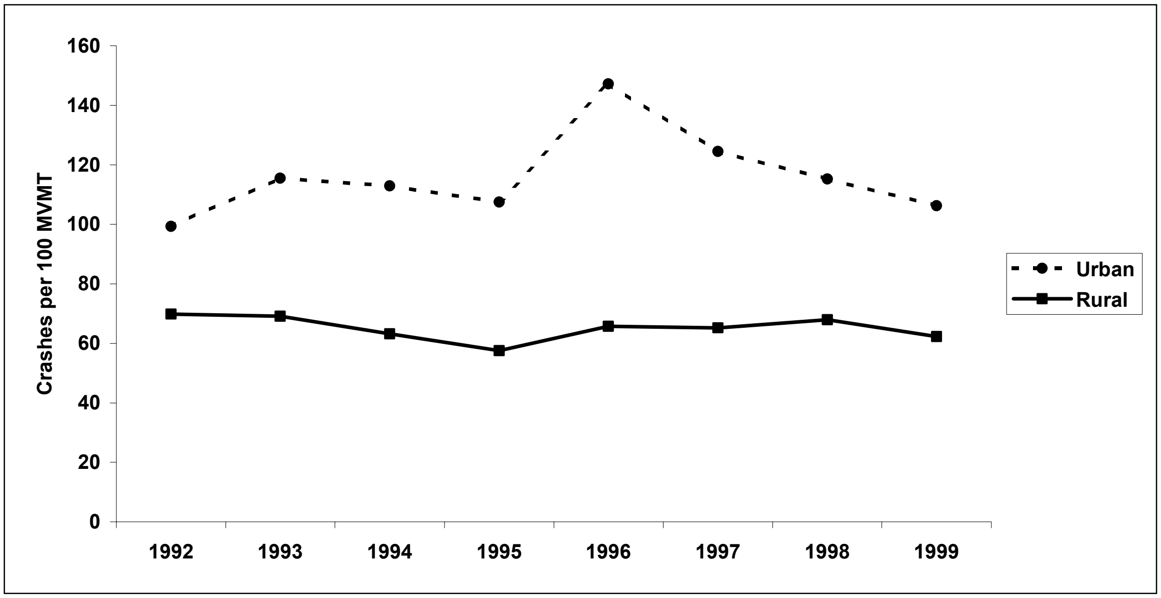
Speed limit increases posted 12/95 (urban segments) and 5/96 (rural segments).

Figure 4. Annual total crashes on Utah Interstate highway, by segment type.



Speed limit increases posted 12/95 (urban segments) and 5/96 (rural segments).

Figure 5. Annual total crash rates on Utah Interstate highways, by segment type.



Speed limit increases posted 12/95 (urban segments) and 5/96 (rural segments).

Fatal Crashes on Interstates

Table 8 and Figures 6-7 show the number and rates of fatal crashes on Utah Interstates by year and segment type.

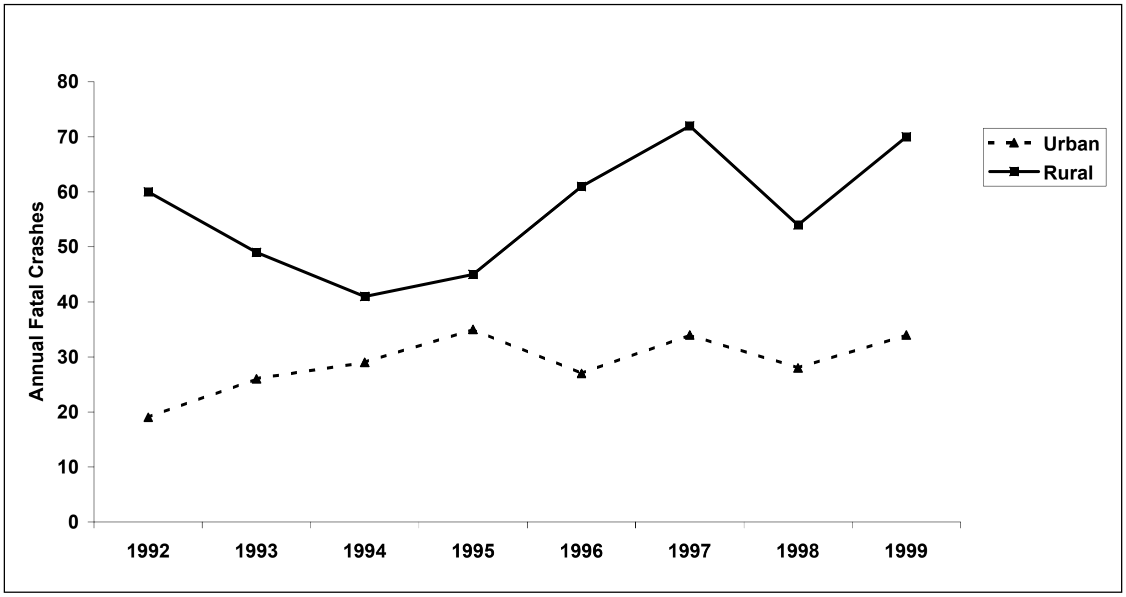
The number of fatal crashes on these roadways was small, 75-100 per year during the study period. Fatal crash rates through the study period showed some differences between urban and rural Interstates. Fatal crash rates on urban Interstates showed some year-to-year variation but no discernable trend over time. Fatal crash rates on rural Interstates showed a decline from 1992-1995, an apparent interruption of the decline in 1996, and apparent increase in 1997 and 1998 compared with 1995-6. Despite the apparent graphical trends, however, intervention time series analysis showed there was no significant effect on fatal crash rates on either urban ($p = .892$) or rural ($p = .369$) segments temporally associated with the increase in posted speed limit.

Table 8. Annual fatal crashes and crash rates on Utah Interstates by segment type, total number and percent of all crashes.

% of all crashes = percent of all crashes on that segment type associated with fatality.
Speed limit increases posted 12/95 (urban segments) and 5/96 (rural segments).

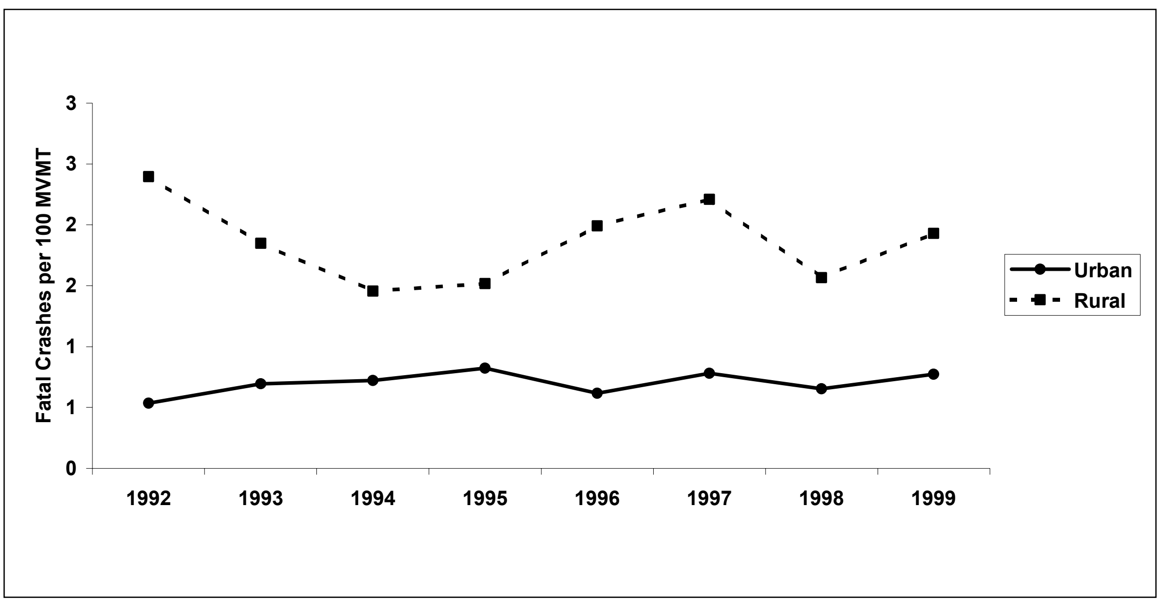
		1992	1993	1994	1995	1996	1997	1998	1999
Urban	Fatal Crashes	19	26	29	35	27	34	28	34
	% of all Urban Crashes	0.5%	0.6%	0.6%	0.8%	0.4%	0.6%	0.6%	0.7%
	Fatal Crash Rates per 100 MVMT	0.53	0.69	0.72	0.82	0.62	0.78	0.65	0.77
Rural	Fatal Crashes	60	49	41	45	61	72	54	70
	% of all Rural Crashes	3.4%	2.7%	2.3%	2.6%	3.0%	3.4%	2.3%	3.1%
	Fatal Crash Rates per 100 MVMT	2.40	1.85	1.46	1.52	1.99	2.21	1.57	1.93

Figure 6. Annual fatal crashes on Utah Interstates by segment type.



Speed limit increases posted 12/95 (urban segments) and 5/96 (rural segments).

Figure 7. Annual fatal crash rates on Utah Interstate highways, by segment type.



Speed limit increases posted 12/95 (urban segments) and 5/96 (rural segments).

Injury Crashes on Utah Interstates.

Table 9: Accident Severity

Accident Severity 1. No injury 2. Possible injury 3. Bruises and abrasions 4. Broken bones or bleeding wounds 5. Fatal

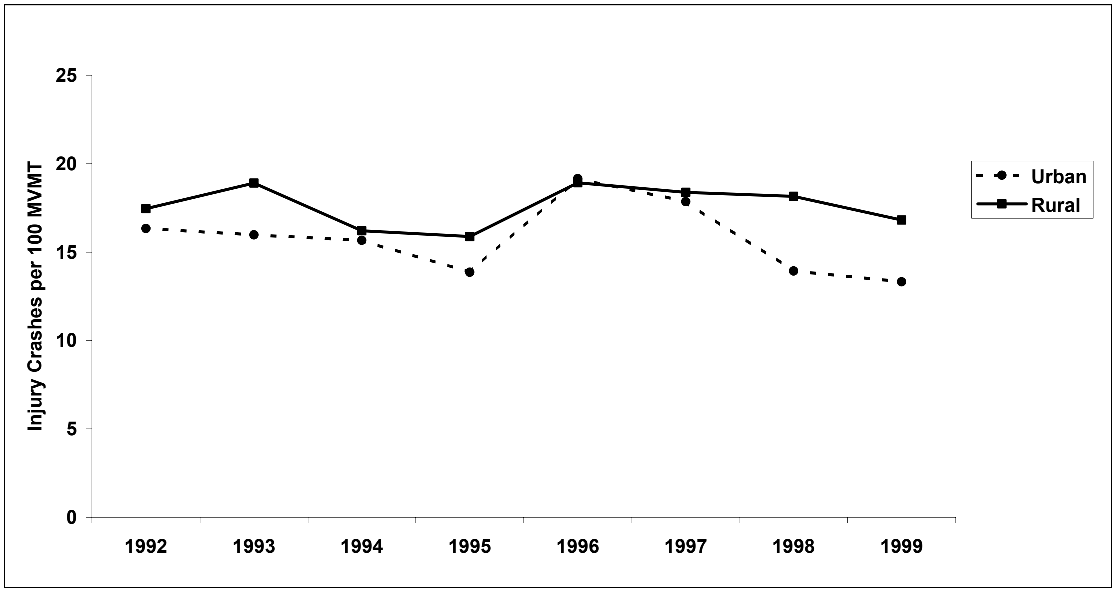
Injury crashes were identified according to police assignment of accident severity as noted on the crash file, as rated by Utah police (see police crash assessment tools, Appendix and Table 9). (Severity of injury could also be inferred from the linkages with the hospital file, see the following section.) Since police are not necessarily expert in the identification of injured persons, only obvious injuries were included, specifically severity levels 3 (bruises and abrasions) and 4 (broken bones or bleeding wounds). Severity level 2 (possible injury) was excluded.

Injury crash number and rates are shown in Table 10 and Figure 9. There was a progressive increase in the raw number of injury crashes on rural segments for the years of the study period. Urban segments showed an increase for 1996, followed by a continual decline back to similar numbers as were seen in the early 1990s. When injury crash rates was calculated, similar patterns were seen for rural and urban segments, with an apparent increase in injury crash rates for the years of 1996-7, followed by a progressive slow decline. Despite the apparent graphical trends, however, intervention time series analysis showed there was no significant effect on injury crash rates on either urban (p = .29) or rural (p = .132) segments temporally associated with the increase in posted speed limit. We then examined the proportion of all crashes on these roadways that resulted in injury, and found no perceptible trend or pattern over time.

Table 10. Annual injury crashes and injury crash rates on Utah Interstate highways, by segment type.
% of all crashes = percent of all crashes on that segment type associated with injury.
Speed limit increases posted 12/95 (urban segments) and 5/96 (rural segments).

		1992	1993	1994	1995	1996	1997	1998	1999
Urban	Injury Crashes	581	598	630	590	840	778	596	585
	% of all Urban Crashes	16.4%	13.8%	13.9%	12.9%	13.0%	14.3%	12.1%	12.5%
	Injury Crash Rates per 100 MVMT	16.33	15.98	15.67	13.86	19.16	17.85	13.92	13.31
Rural	Injury Crashes	437	501	456	471	580	599	626	610
	% of all Rural Crashes	25.0%	27.3%	25.6%	27.6%	28.8%	28.2%	26.7%	27.0%
	Injury Crash Rates per 100 MVMT	17.46	18.91	16.20	15.87	18.92	18.38	18.16	16.81

Figure 8. Injury crash rates on Utah Interstate highways, by segment type.



Speed limit increases posted 12/95 (urban segments) and 5/96 (rural segments).

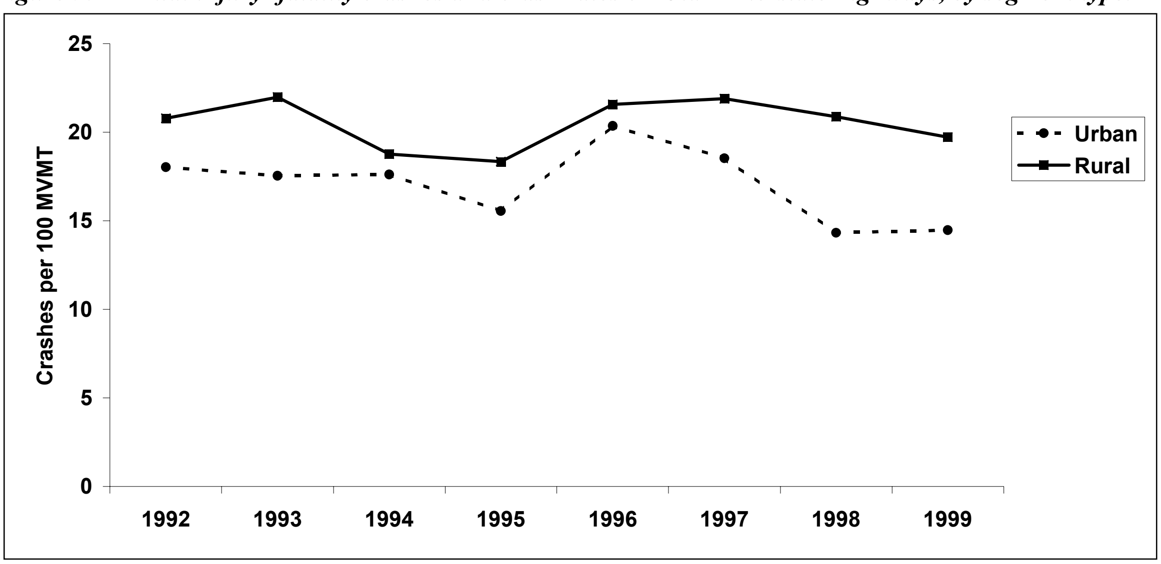
__Injury + Fatality Crashes on Utah Interstates__

Injury and fatality crashes were identified as noted in the previous section. The rates of injury and fatality crashes combined are shown in Table 11 and Figure 9; Table 11 also shows the percentage of all crashes that were associated with injury or fatality. There was a progressive increase in the raw number of injury+fatality crashes on rural segments for the years of the study period. Urban segments showed an increase for 1996, followed by a continual decline back to similar numbers as were seen in the early 1990s. When rates were calculated, similar patters were seen for rural and urban segments, with an increase in injury+fatality crash rates for the years of 1996-7, followed by a progressive slow decline. Despite the apparent graphical trends, however, intervention time series analysis showed there was no significant effect on injury+fatality crash rates on either type of segments temporally associated with the increase in posted speed limit. We then examined the proportion of all crashes on these roadways that resulted in injury or fatality, and found no perceptible trend or pattern over time.

Table 11. Annual injury+fatality crashes, crash rates and percentage of all crashes on Utah Interstate highways, by segment type.
% of all crashes = percent of all crashes on that segment type associated with injury or fatality.
Speed limit increases posted 12/95 (urban segments) and 5/96 (rural segments).

		1992	1993	1994	1995	1996	1997	1998	1999
Urban	Injury+Fatality Crash Rates per 100 MVMT	18.0	17.5	17.6	15.5	20.3	18.5	14.3	14.5
	% of all Crashes	17.0%	14.4%	14.5%	13.7%	13.4%	15.0%	12.7%	13.3%
Rural	Injury+Fatality Crash Rates per 100 MVMT	20.8	22.0	18.8	18.3	21.6	21.9	20.9	19.7
	% of all Crashes	28.4%	30.0%	28.0%	30.2%	31.8%	31.6%	29.0%	30.1%

Figure 9. Annual injury+fatality crashes and crash rates on Utah Interstate highways, by segment type.



Speed limit increases posted 12/95 (urban segments) and 5/96 (rural segments).

Interstate Crash Files Linkage to Hospital File

Table 12. Crashes on Utah Interstates: Number and proportion of crash records linking to inpatient hospital records, by year and segment type.
Speed limit increases posted 12/95 (urban segments) and 5/96 (rural segments).

		1992	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*
Crash-Inpatient Links	**Urban**	106	79	90	95	136	132	91
	Rural	105	107	89	110	151	106	85
Crash-Inpatient Links per Crash	**Urban**	0.030	0.018	0.020	0.021	0.021	0.024	0.018
	Rural	0.060	0.058	0.050	0.064	0.075	0.050	0.036

The number and proportion of crash records that could be linked to the hospital inpatient file is shown in Table 12. For urban segments, there was an apparent increase in the number of links in 1996 and 1997 compared with previous years, with a decrease in 1998. For rural segments, there appeared to be an increase in both the number and proportion of crash file – hospital file links for the years 1995 and 1996, with a progressive decline in the subsequent years to lower values. Note that the crash record is a crash-level file, with one record generated for each crash event no matter the number of people or vehicles involved. It is therefore possible to have more than one link with the hospital record for a given crash, if more than one person was hospitalized as a result of the crash. The proportion of crashes that could be linked to the hospital file exhibited no particular trend over time, showing no changes temporally associated with speed limit increase.

Table 13. Inpatient hospital charges resulting from crashes on Utah Interstate highways, 1992-1998, by year and segment type.
Speed limit increases posted 12/95 (urban segments) and 5/96 (rural segments).

	1992	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Total Inpatient Charges, $ Million	2.214	1.884	2.175	2.729	3.237	2.963	2.042
Mean Inpatient Charges per Linked Crash, $	10492	10130	12148	13314	11280	12450	11599

Table 13 shows the total inpatient charges for medical care for crash records that linked to hospital inpatient records, and the mean hospital charges for link. No trends or patterns could be discerned through the years of the study, and there were no changes temporally associated with speed limit increase.

Interstate Single Vehicle Crashes

Single vehicle crashes were identified from two fields in the crash file, "Type of accident" (Table 14 and Appendix page A1) and "Type of Collision" (Appendix page A3). Crashes were assigned a rating for each of these variables; the two were not mutually exclusive. We analyzed those types of crashes that would identify driver losing control of the vehicle, running off the road (accident types 9, R, L) and all single vehicle crashes (collision type 17). There was a progressive increase in the number of these types of crashes over the study period, however there was no discernable change in the proportion of all crashes that they comprised (Tables 15-17).

Table 14. Crash type categories.

Type of Accident

1. MV – pedestrian
2. MV – MV
3. MV – train
4. MV – bicycle
5. MV – animal (wild)
6. MV – fixed object
7. MV – other object
8. Overturned
9. Ran off roadway – thru median

R. Ran off road – right
L. Ran off road – left
A. Other non-collision
D. MV – animal (domestic)

Table 15. Annual crashes on Utah Interstates of single vehicle running off road types, by segment type.
Speed limit increases posted 12/95 (urban segments) and 5/96 (rural segments).

		1992	1993	1994	1995	1996	1997	1998	1999
Ran off road median	**Urban**	95	87	128	144	155	135	208	189
	Rural	93	136	204	164	129	197	352	352
Ran off road left	**Urban**	262	371	382	294	546	473	200	227
	Rural	323	371	286	301	419	385	248	309
Ran off road right	**Urban**	334	431	440	403	649	528	411	375
	Rural	361	437	430	393	513	553	572	502
Total		1468	1833	1870	1699	2411	2271	1991	1954

Table 16: Annual crashes on Utah Interstates of single vehicle running off road type, percentage of all crashes, by segment type.
Speed limit increases posted 12/95 (urban segments) and 5/96 (rural segments).

		1992	1993	1994	1995	1996	1997	1998	1999
Ran off road median	**Urban**	2.69%	2.01%	2.82%	3.15%	2.40%	2.49%	4.22%	4.05%
	Rural	5.32%	7.42%	11.49%	9.61%	6.41%	9.27%	15.02%	15.58%
Ran off road left	**Urban**	7.41%	8.58%	8.42%	6.43%	8.46%	8.72%	4.06%	4.86%
	Rural	18.47%	20.24%	16.10%	17.63%	20.83%	18.11%	10.58%	13.67%
Ran off road right	**Urban**	9.45%	9.97%	9.70%	8.81%	10.06%	9.73%	8.33%	8.03%
	Rural	20.64%	23.84%	24.21%	23.02%	25.50%	26.01%	24.41%	22.21%
Total	**Urban**	19.55%	20.57%	20.94%	18.39%	20.93%	20.94%	16.61%	16.94%
	Rural	44.43%	51.50%	51.80%	50.26%	52.73%	53.39%	50.02%	51.46%
Total		27.79%	29.78%	29.63%	27.06%	28.49%	30.08%	27.37%	28.20%

Table 17. Annual single-vehicle crashes on Utah interstates, number and proportion of all interstate crashes, by segment type.
Speed limit increases posted 12/95 (urban segments) and 5/96 (rural segments).

	1992	1993	1994	1995	1996	1997	1998	1999
Urban	1362	1550	1684	1640	2263	2087	1907	1665
Rural	1439	1452	1435	1399	1588	1723	1797	1813
Urban % of all crashes	38.5%	35.9%	37.1%	35.9%	35.1%	38.5%	38.7%	35.7%
Rural % of all crashes	27.2%	23.6%	22.7%	22.3%	18.8%	22.8%	24.7%	26.2%

Non-Interstate Highways Analyzed

Speed limits on all Utah non-Interstate highways were examined. Highways were chosen for analysis if they included any segment of road for which the speed limit was currently 60-65 mph. Speed limits higher than 55 mph were not permitted for such highways under NMSL, so that current speed limits of 60 or 65 mph would identify highways segments where speed limit was changed as a result of NMSL repeal. Thirty-six highways were identified as having segments of 60-65 mph speed limit. All these roads obviously were rural for at least part of their length in order to have 60-65 speed limit designation, but most also passed through cities and towns and thus had lower speed limits for other segments. As can be seen in Table 18, however, roughly 70% of the mileage of these selected highways did undergo increase in speed limit.

Table 18. Mileage by Speed Limit on non-Interstate Highways Analyzed

Speed Limit	Mileage	Percent
25	0.4	0.0%
30	32.1	1.3%
35	52.7	2.1%
40	111.6	4.5%
45	73.4	3.0%
50	79.6	3.2%
55	403.3	16.3%
60	145.7	5.9%
65	1571.8	63.6%
Total	2470.6	

Analysis of the impact of these speed limit changes was complicated by the nature of these highways. The same highway may traverse both unpopulated desert and become a city street in Utah's most densely populated urban centers. Speed limits on such highways are in a constant state of flux. Partly as a result of this, speed limit increases on these highways subsequent to NMSL repeal did not occur at a single point in time, but were spread out over more than a year. As can be seen in Table 19, speed limits were increased to 60-65 mph beginning in late 1996, about 6 months after such changes became effective on most Interstate Highways, and occurred throughout 1997, being 97% complete by the end of that year.

Table 19. Posting of 60 and 65 mph speed limits on non-Interstate highways analyzed. *Mileage of posting and percent completed by quarter*.

Quarter	Mileage Affected	Cumulative Percent
4th quarter 1996	54.7	3.2%
1st quarter 1997	722.2	45.2%
2nd quarter 1997	368.8	66.7%
3rd quarter 1997	448.3	92.8%
4th quarter 1997	88.2	97.9%
1st quarter 1998	10.0	98.5%
2nd quarter 1998	7.6	99.0%
3rd quarter 1998	0.0	
4th quarter 1998	17.7	100.0%
Total	1717.5	

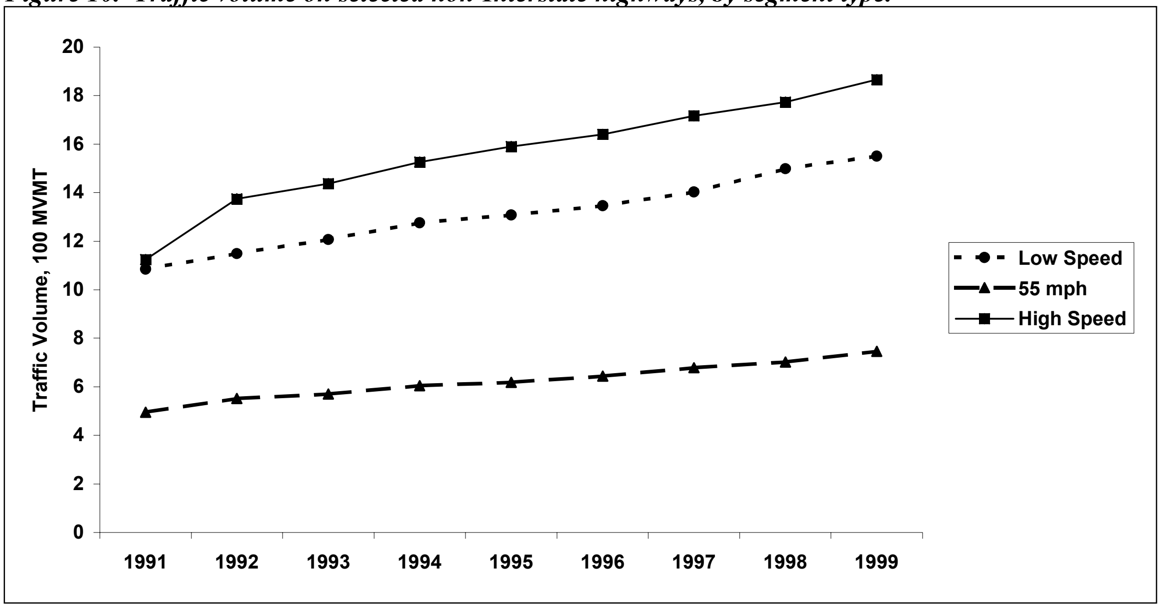
As was done for Interstate highways, non-Interstate highway segments were aggregated into categories for analysis. It seemed reasonable to make the following three generalizations of segment types.

1. Low-speed segments: These may be either rural or urban, but have current speed limits of 50 mph or less. Speed limits on these segments would not have been affected by NMSL repeal.
2. 55 mph segments: These are rural highways with current speed limits of 55 mph. These segments had speed limits of 55 mph prior to NMSL repeal as well. Speed limits on these segments would not have been affected by NMSL repeal.
3. High-speed segments: These are rural segments with current speed limits of 60 or 65 mph. These speed limits would have been in effect only after NMSL repeal.

Speed limits changes occurred at intervals on all types of roads and highways throughout the study period. However, only the changes on segments in the "high-speed" category above were the result of NMSL repeal.

Figure 10 shows trends in traffic volume on the selected non-Interstate highways over the 9-year period 1991-99. There was a linear increase in traffic volume for all three types of segments, low-speed, 55 mph, and high-speed. For the entire 9-year period, there was an aggregate increase in traffic volume of approximately 43% for low speed, 51% for 55 mph, and 66% for high-speed segments respectively.

Figure 10. Traffic volume on selected non-Interstate highways, by segment type.



Highways selected if they included segments of 60 or 65 mph speed limit.
Low-speed: Current speed limit 50 mph or less. 55 mph: Current speed limit 55 mph. High-speed: Current speed limit 60 or 65 mph. Increased speed limit posted throughout 1997 (high-speed segments only).

Total Crashes on Utah non-Interstate Highways

Table 20 and Figures 11-12 show total crash number and rates on the selected non-Interstate highways by year and roadway type.

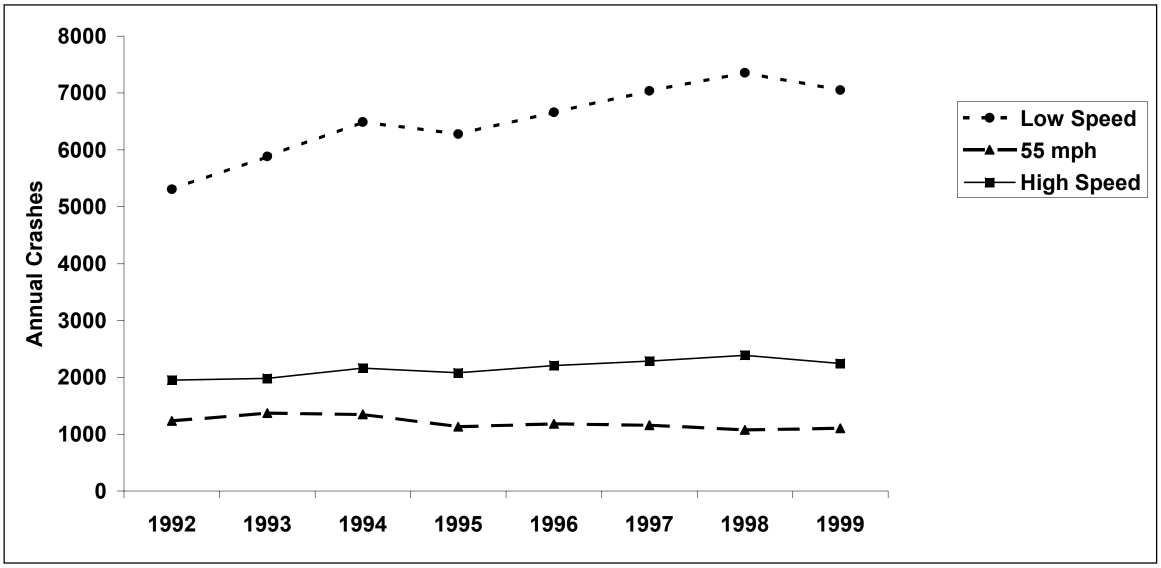
The number of total crashes on low speed segments (unaffected by NMSL repeal) showed a progressive increase, approximately 33% over the entire time interval. There was no notable trend in the number of annual total crashes on either 55 mph or high-speed segments.

Total crash rates on non-Interstate highways showed variability year-to-year. Overall, there was a progressive decline in the total crash rates for all three types of segments, low speed, 55 mph, and high-speed. Total crash rates in the final year of the study, 1999, were the lowest encountered during the study period for all three types of road segments. Intervention time series analysis showed there was no significant effect on total crash rates on high-speed segments associated with the increase in posted speed limit (p = .253). Neither was there any significant increase in total crash rates on low-speed or 55 mph segments (p = .766 and .167 respectively), although posted speed limit was unchanged on these segment types.

Table 20. Annual total crashes and crash rates on selected Utah non-Interstate highways, by segment type.
Highways selected if they included segments of 60 or 65 mph speed limit.
Increased speed limit posted throughout 1997 (high-speed segments only).

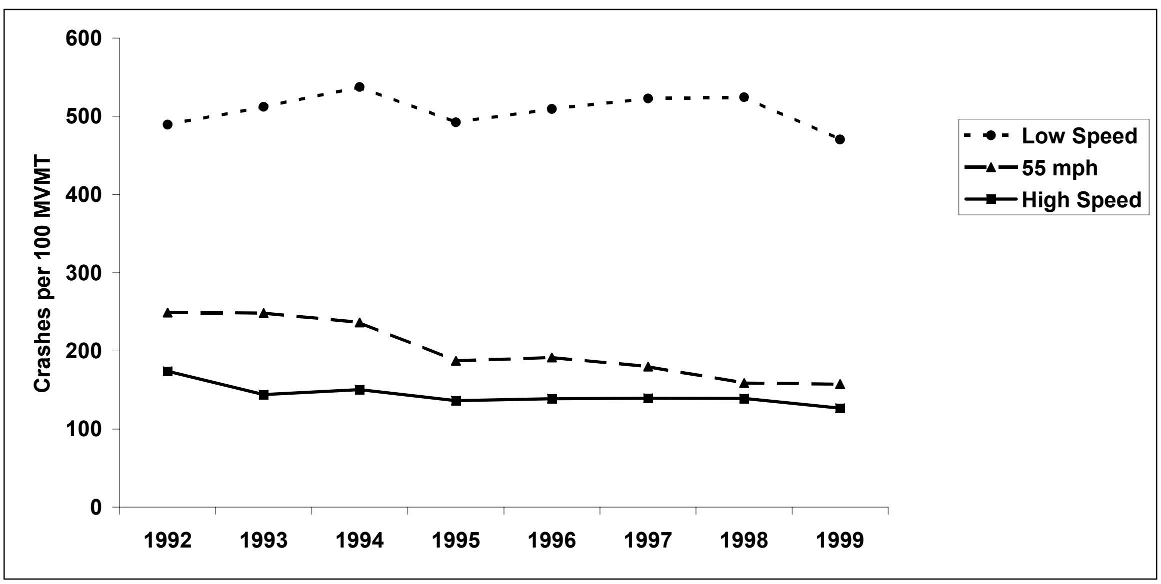
		1992	1993	1994	1995	1996	1997	1998	1999
Low Speed	Crashes	5309	5885	6490	6280	6662	7038	7356	7051
	Crash Rates per 100 MVMT	489.47	512.15	537.63	492.36	509.33	522.81	524.30	470.30
55 mph	Crashes	1232	1371	1348	1132	1183	1159	1078	1106
	Crash Rates per 100 MVMT	249.01	248.35	236.22	187.08	191.38	179.80	158.80	157.53
High Speed	Crashes	1952	1981	2160	2081	2207	2286	2387	2246
	Crash Rates per 100 MVMT	173.67	144.15	150.27	136.42	138.84	139.41	139.00	126.65

Figure 11. Annual total crashes on selected Utah non-Interstate highways, by segment type.
Highways selected if they included segments of 60 or 65 mph speed limit.



Low-speed: Current speed limit 50 mph or less. 55 mph: Current speed limit 55 mph. High-speed: Current speed limit 60 or 65 mph. Increased speed limit posted throughout 1997 (high-speed segments only).

Figure 12. Annual total crash rates on selected Utah non-Interstate highways, by segment type
Highways selected if they included segments of 60 or 65 mph speed limit.



Low-speed: Current speed limit 50 mph or less. 55 mph: Current speed limit 55 mph. High-speed: Current speed limit 60 or 65 mph. Increased speed limit posted throughout 1997 (high-speed segments only).

Fatal Crashes on non-Interstate Highways

Table 21 and Figures 13-14 show number and rates of fatal crashes on the selected segments of Utah non-Interstate highways. Table 21 also shows the proportion of all crashes on the selected segments associated with a fatality.

Number of fatal crashes showed variation from year-to-year, and patterns seen appeared to differ between the three segment types. There were no clear trends for low speed and 55 mph segments. For high-speed segments, there did appear to be a progressive increase in fatal crash number over time. In particular, there did appear to be a "spike" in crash number in 1997 for high-speed segments, the year in which posted speed limits were changed for these segments.

Fatal crash rates showed variation from year-to-year. There did appear to be a "spike" in fatal crash rates in 1997-1998 for 55 mph and high-speed segments. The fatal crash rates on these segment types appeared to be lower again in 1999. Although the posting of increase speed limits occurred mostly during calendar year 1997, 55 mph segments were not generally affected. Intervention time series analysis showed that the fatal crash rates on high-speed segments was significantly increased associated with the increase posted speed limits ($p = .039$). There was no significant effect on fatal crash rates on low-speed or 55 mph segments associated with the increase in posted speed limit ($p = .846$ and $.685$ respectively).

Also, the proportion of all crashes that were associated with a fatality on both 55 mph and high speed segments appeared to be higher in 1997 and 1998. The number of fatal crashes, and the proportion associated with fatality, on these segment types appeared to be lower again in 1999. Although the posting of increase speed limits occurred mostly during calendar year 1997, 55 mph segments were not generally affected.

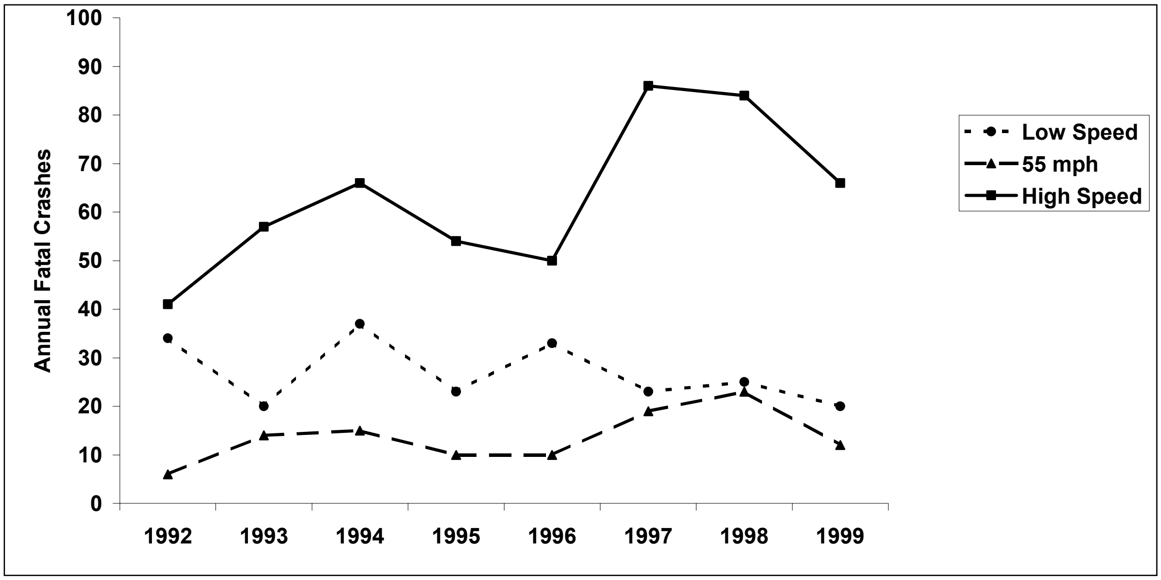
It must be noted that the absolute number of fatal crashes for any year and segment type is small, less than 100 in every case. Thus, there is likely much random variation in these numbers, and caution should be used in identifying possible trends and effects over time.

Table 21. Annual fatal crashes and crash rates on selected Utah non-Interstate highways, by segment type.
Highways selected if they included segments of 60 or 65 mph speed limit.

		1992	1993	1994	1995	1996	1997	1998	1999
Low Speed	Fatal Crashes	34	20	37	23	33	23	25	20
	% of all Low Speed Crashes	0.64%	0.34%	0.57%	0.37%	0.50%	0.33%	0.34%	0.28%
	Fatal Crash Rates per 100 MVMT	3.13	1.74	3.07	1.80	2.52	1.71	1.78	1.33
55 mph	Fatal Crashes	6	14	15	10	10	19	23	12
	% of all 55 mph Crashes	0.49%	1.02%	1.11%	0.88%	0.85%	1.64%	2.13%	1.08%
	Fatal Crash Rates per 100 MVMT	1.21	2.54	2.63	1.65	1.62	2.95	3.39	1.71
High Speed	Fatal Crashes	41	57	66	54	50	86	84	66
	% of all High Speed Crashes	2.10%	2.88%	3.06%	2.59%	2.27%	3.76%	3.52%	2.94%
	Fatal Crash Rates per 100 MVMT	3.65	4.15	4.59	3.54	3.15	5.24	4.89	3.72

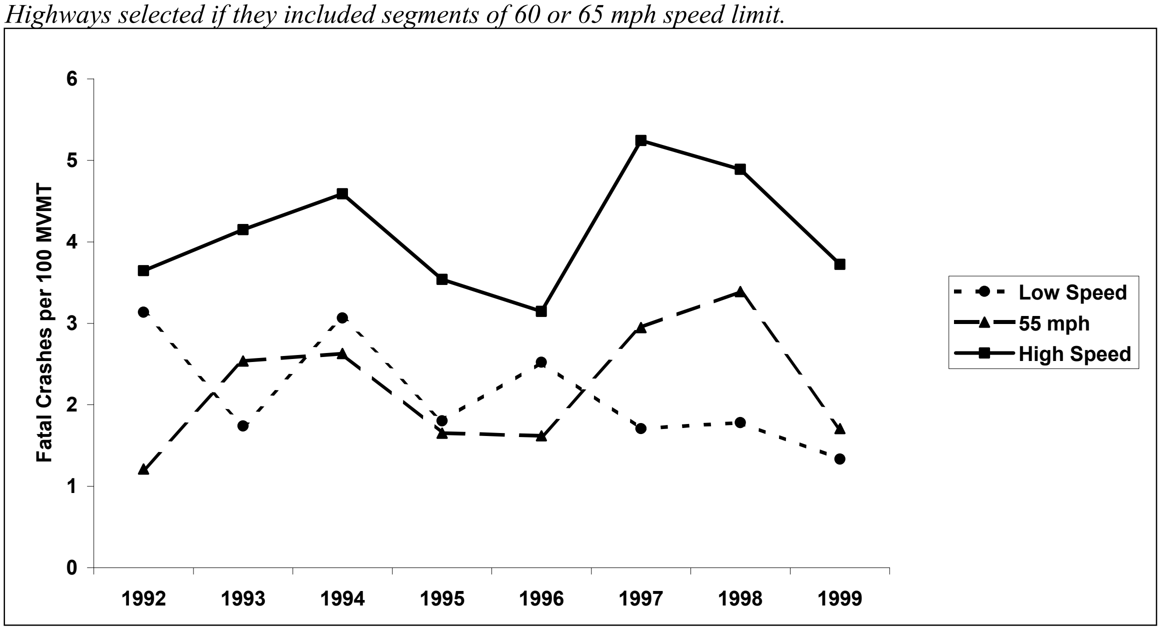
Crash number and % of all crashes that were associated with fatality on segment type.
Low-speed: Current speed limit 50 mph or less. 55 mph: Current speed limit 55 mph. High-speed: Current speed limit 60 or 65 mph. Increased speed limit posted throughout 1997 (high-speed segments only).

Figure 13. Annual fatal crashes on selected Utah non-Interstate highways, by segment type.
Highways selected if they included segments of 60 or 65 mph speed limit.



Low-speed: Current speed limit 50 mph or less. 55 mph: Current speed limit 55 mph. High-speed: Current speed limit 60 or 65 mph. Increased speed limit posted throughout 1997 (high-speed segments only).

Figure 14. Annual fatal crash rates on selected Utah non-Interstate highways, by segment type.
Highways selected if they included segments of 60 or 65 mph speed limit.



Low-speed: Current speed limit 50 mph or less. 55 mph: Current speed limit 55 mph. High-speed: Current speed limit 60 or 65 mph. Increased speed limit posted throughout 1997 (high-speed segments only).

Injury Crashes on non-Interstate Highways

Table 22 and Figures 15-16 show number and rates of injury crashes on the selected segments of non-Interstate highways. Table 20 also shows the proportion of all crashes on the selected segments associated with an injury.

Number of injury crashes showed year-to-year variability. There was, however, no obvious trend over time for any of the three types of segments for either the total number of injury crashes or the proportion of all crashes that resulted in injury.

Injury crash rates showed year-to-year variability, but overall there was a suggestion of a slow downward trend in injury crash rates for all three segment types. The decrease in crash rates on high-speed segments was smaller than the decrease seen for low-speed and 55 mph segments. Intervention time series analysis showed no significant affect on crash rates on high-speed segments temporally associated with change in posted speed limit (p = .163). Neither was there any such effect on low-speed (p = .715) or 55 mph (p = .824) segments).

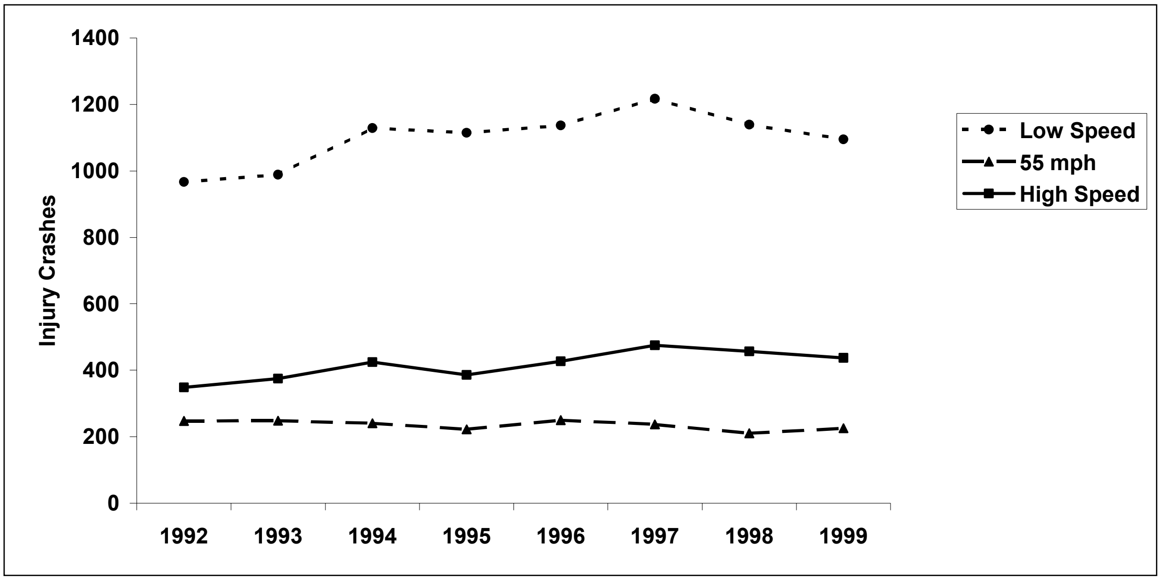
Also, the proportion of all crashes that were associated with an injury did not change over time for any segment type.

Table 22. Annual injury crashes and injury crash rates on selected Utah non-Interstate highways, by segment type.
Highways selected if they included segments of 60 or 65 mph speed limit.

		1992	1993	1994	1995	1996	1997	1998	1999
Low Speed	Injury Crashes	967	989	1129	1115	1137	1217	1139	1095
	% of all Low Speed Crashes	18%	17%	17%	18%	17%	17%	15%	16%
	Injury Crash Rates per 100 MVMT	84.2	81.9	88.5	85.2	84.5	86.7	76.0	70.6
55 mph	Injury Crashes	247	248	240	222	250	237	210	225
	% of all 55 mph Crashes	20%	18%	18%	20%	21%	20%	19%	20%
	Injury Crash Rates per 100 MVMT	44.7	43.5	39.7	35.9	38.8	34.9	29.9	30.1
High Speed	Injury Crashes	348	375	425	386	427	475	457	437
	% of all High Speed Crashes	18%	19%	20%	19%	19%	21%	19%	19%
	Injury Crash Rates per 100 MVMT	25.3	26.1	27.9	24.3	26.0	27.7	25.8	23.4

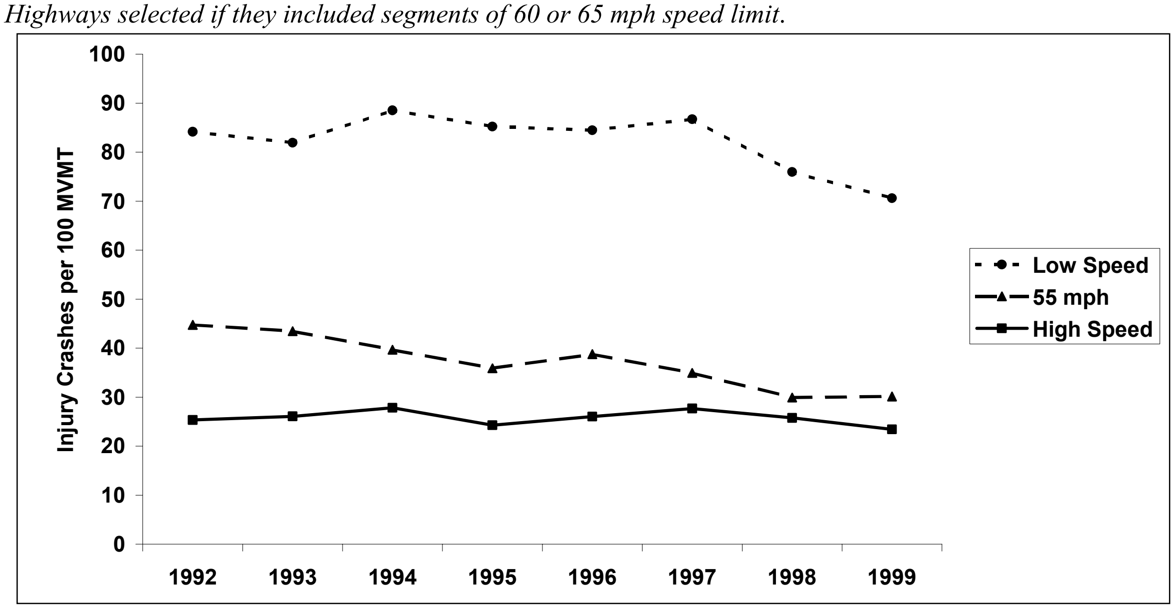
Low-speed: Current speed limit 50 mph or less. 55 mph: Current speed limit 55 mph. High-speed: Current speed limit 60 or 65 mph. Increased speed limit posted throughout 1997 (high-speed segments only).

Figure 15. Annual injury crashes on selected Utah non-Interstate highways, by segment type.
Highways selected if they included segments of 60 or 65 mph speed limit..



Low-speed: Current speed limit 50 mph or less. 55 mph: Current speed limit 55 mph. High-speed: Current speed limit 60 or 65 mph. Increased speed limit posted throughout 1997 (high-speed segments only).

Figure 16. Annual injury crash rates on selected Utah non-Interstate highways, by segment type.
Highways selected if they included segments of 60 or 65 mph speed limit.



Low-speed: Current speed limit 50 mph or less. 55 mph: Current speed limit 55 mph. High-speed: Current speed limit 60 or 65 mph. Increased speed limit posted throughout 1997 (high-speed segments only).

Injury+Fatality Crashes on non-Interstate Highways

Table 23 and Figure 17 show the rates of combined injury and fatal crashes on the selected segments of non-Interstate highways. Table 21 also shows the proportion of all crashes on the selected segments associated with an injury or fatality.

Combined injury+fatality crash rates showed year-to-year variability, but overall there was a suggestion of a slow downward trend for all three segment types. There was no significant effect on rates at the time when posted speed limits were increased for any segment type.

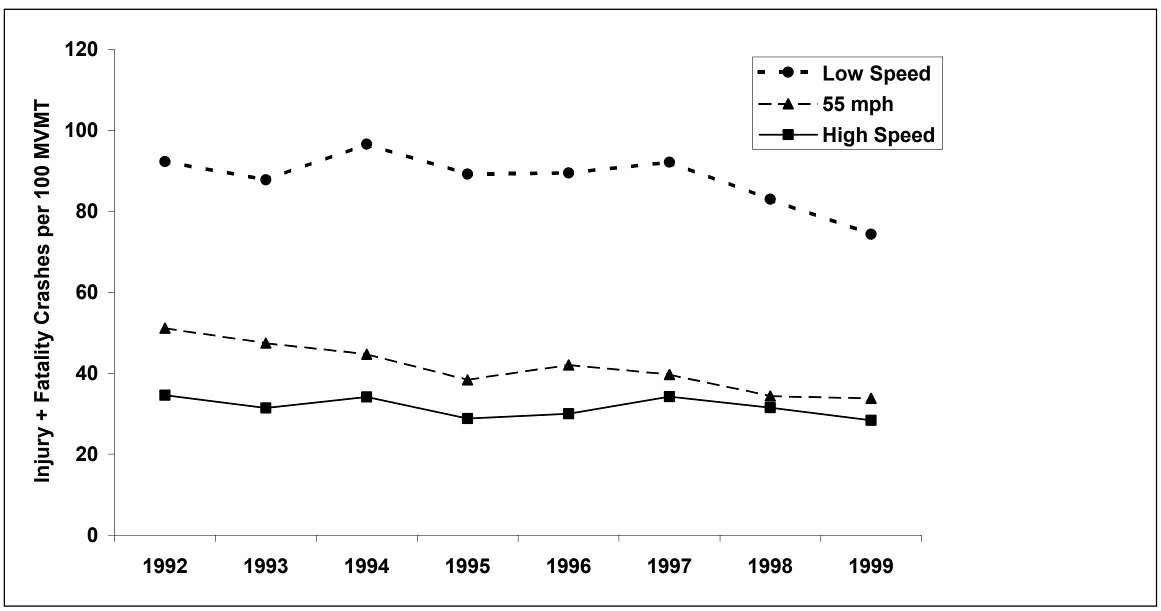
Also, the proportion of all crashes that were associated with an injury or fatality did not change over time for any segment type.

Table 23. Annual rates of crashes, and percent of all crashes, that resulted in injury or fatality, on selected Utah non-Interstate highways, by segment type.
Highways selected if they included segments of 60 or 65 mph speed limit.

		1992	1993	1994	1995	1996	1997	1998	1999
Low Speed	Injury+Fatality Crash Rates per 100 MVMT	92.3	87.8	96.6	89.2	89.4	92.1	83.0	74.4
	% of all Crashes	19%	17%	18%	18%	18%	18%	16%	16%
55 mph	Injury+Fatality Crash Rates per 100 MVMT	51.1	47.5	44.7	38.3	42.1	39.7	34.3	33.8
	% of all Crashes	21%	19%	19%	20%	22%	22%	22%	21%
High Speed	Injury+Fatality Crash Rates per 100 MVMT	34.6	31.4	34.2	28.8	30.0	34.2	31.5	28.4
	% of all Crashes	20%	22%	23%	21%	22%	25%	23%	22%

Low-speed: Current speed limit 50 mph or less. 55 mph: Current speed limit 55 mph. High-speed: Current speed limit 60 or 65 mph. Increased speed limit posted throughout 1997 (high-speed segments only).

Figure 17. Annual rates of crashes that resulted in injury or fatality on selected Utah non-Interstate highways, by segment type.
Highways selected if they included segments of 60 or 65 mph speed limit.



Low-speed: Current speed limit 50 mph or less. 55 mph: Current speed limit 55 mph. High-speed: Current speed limit 60 or 65 mph. Increased speed limit posted throughout 1997 (high-speed segments only).

Crashes on non-Interstate highways; linkage to hospital inpatient records

Table 24 shows linkage of records in the crash file to the hospital inpatient file for the years 1992-1998. Each link represents a crash that was associated with an inpatient admission. There was considerable variation from year to year for each segment type. The number of links and the links per crash appeared to decline progressively through time, however, for all three segment types. Mean hospital charges per link varied widely for each segment type, with the highest and lowest values differing by 2-3 fold for each type, and no pattern over time could be discerned.

Table 24. Linkage of crashes to hospital files on selected Utah non-Interstate highways, by segment type.
Number and proportion of crash records linking to inpatient hospital records, by year. Increased speed limit posted throughout 1997 (high-speed segments only).
Highways selected if they included segments of 60 or 65 mph speed limit.

		1992	1993	1994	1995	1996	1997	1998
Links to Hospital Inpatient File	Low Speed	134	133	154	111	142	156	84
	55 mph	52	53	41	38	60	51	27
	High Speed	82	86	83	73	139	95	59
Links per Crash	Low Speed	0.025	0.023	0.024	0.018	0.021	0.022	0.011
	55 mph	0.042	0.039	0.030	0.034	0.051	0.044	0.025
	High Speed	0.042	0.043	0.038	0.035	0.063	0.042	0.025
Charges per Link	Low Speed	$4,317	$3,133	$3,184	$7,953	$11,249	$6,533	$6,714
	55 mph	$5,529	$15,812	$12,546	$12,925	$8,282	$15,262	$13,278
	High Speed	$14,207	$9,292	$16,196	$17,876	$8,427	$23,166	$21,286

Single Vehicle Crashes on Utah non-Interstate Highways

Tables 25-27 show the number of single vehicle crashes on non-Interstate highways for 55 mph and high speed segments for 1992-1999. The crash file categorizes these in two separate ways, "ran off road" (Tables 25-26) and "single vehicle" (Table 27); these two categories are not mutually exclusive. There was no identifiable trend in either the number of such crashes or in the proportion of all crashes that they comprised.

Table 25. Annual crashes involving single vehicles running off roadway on selected Utah non-Interstate highways, by segment type.
Highways selected if they included segments of 60 or 65 mph speed limit.

		1992	1993	1994	1995	1996	1997	1998	1999
Ran off road median	55 mph	7	12	15	13	13	7	9	4
	High Speed	9	16	40	28	27	26	38	21
Ran off road left	55 mph	47	50	44	35	50	39	46	57
	High Speed	128	172	180	157	204	185	216	207
Ran off road right	55 mph	95	111	100	110	131	123	83	108
	High Speed	291	334	372	335	416	468	423	429

Table 26. Annual crashes involving single vehicles running off roadway on selected Utah non-Interstate highways, by segment type.
Highways selected if they included segments of 60 or 65 mph speed limit.

		1992	1993	1994	1995	1996	1997	1998	1999
Ran off road all types	55 mph	149	173	159	158	194	169	138	169
	High Speed	428	522	592	520	647	679	677	657
Percent of all crashes	55 mph	12%	13%	12%	14%	16%	15%	13%	15%
	High Speed	22%	26%	27%	25%	29%	30%	28%	29%

Table 27. Annual single vehicle crashes roadway on selected Utah non-Interstate highways, by segment type
Highways selected if they included segments of 60 or 65 mph speed limit..

		1992	1993	1994	1995	1996	1997	1998	1999
Single vehicle crashes	55 mph	669	687	693	714	741	715	688	668
	High Speed	573	598	666	630	578	563	557	547
Percent of all crashes	55 mph	54%	50%	51%	63%	63%	62%	64%	60%
	High Speed	29%	30%	31%	30%	26%	25%	23%	24%

55 mph: Current speed limit 55 mph. High-speed: Current speed limit 60 or 65 mph. Increased speed limit posted throughout 1997 (high-speed segments only).

DISCUSSION

In this study, we have essayed an analysis of the effect of speed limit increases subsequent to NMSL repeal, on total, fatality-associated, and injury-associated crashes on Utah Interstate and selected non-Interstate highways. We analyzed all Interstate highways and those non-Interstate highways that contain segments where speed limits were increased subsequent to NMSL repeal. In brief, we found that:

1. On urban Interstate segments (current speed limit 60-65 mph) there was a significant increase in total crash rates, but no significant change in fatality or injury crash rates;
2. On rural Interstate segments (current speed limit 70-75 mph), there was no significant change in rates for any category of crash;
3. On high speed non-Interstate highways (current speed limit 60-65 mph), there was a significant increase in fatality crash rates, but no change in total or injury crash rates;
4. On low-speed and 55 mph non-Interstate highways segments, there was no significant change in rates for any category of crash;
5. On both Interstate and non-Interstate highways, for all segment types, there was no discernable increase in injury likelihood or severity.

Our study was observational in nature, observing changes in crash number, rates, and certain other crash characteristics over a time period that included dates of speed limit change. It does not prove causation, however. Any changes or trends observed in crash rates, occurrence or characteristics were temporal associations, not necessarily direct results of speed limit increase.

This study possesses characteristics that make it different from, and possibly more useful than, previous analyses of this topic. These features directly address several recognized shortcomings of the NHTSA-sponsored "The Effect of Increased Speed Limits in the Post-NMSL Era: Report to Congress". (1)

- The study addressed crash rates per vehicle mile traveled, considering the steady increase in traffic volume over time. Many currently available analyses of the effect of NMSL repeal, including the Report to Congress on NMSL repeal, (1) have considered only the annual number of crashes.
- The study addressed crash rates for specific speed limits by road segment, rather than reporting crash rates for groups of highways (with varying speed limits.
- The study addressed, in addition to Interstate highways, those State highways where speed limits were increased subsequent to NMSL repeal.
- The statistical method used in this study, intervention time series analysis, evaluated the effect of NMSL repeal on the ongoing pattern of crash rates on the highways in question, thus considering the ongoing progressive decrease in crash rates on US highways. Other analyzes of crash rates have simply compared crash rates across time and thus might be confounded by this background decrease.

Interstate Highways

Interstate highways were of the greatest interest in this study, because a large proportion of Interstates underwent speed limit increase subsequent to NMSL repeal (approximately 94% of total Interstate mileage), and because the highest speed limit segments (75 mph) are on Interstates. For analysis, Interstate segments were aggregated into rural (current speed limit 70 or 75 mph) and urban (current speed limit 60 or 65 mph) types. As noted previously, posted speed limits on rural Interstates were increased to 75 mph (70 mph for roughly 6% of rural Interstate mileage) during a 2-week period in May 1996. Posted speed limits were increased to 65 mph on urban Interstates for roughly 70% of urban Interstate mileage; the remainder had been posted at 65 mph prior to NMSL repeal.

Traffic volume and crash rates calculations for urban Interstates were confounded by the major Interstate reconstruction project in urban Salt Lake County, which commenced in April 1996. Although this project was commonly known as the "I-15 reconstruction project", it affected to some degree essentially all Interstate mileage in this county during the years 1996-1999. Parts of I-15 and the major 1-15:I-80 interchange were closed or partially closed for roughly two years. Additionally, there were many lane closures, lane narrowing, temporary on- and off- ramp provisions, traffic diversions, barricade erection, etc. Salt Lake County is the largest urbanized area in Utah, so that a sizable proportion (roughly 46%) of all Utah urban Interstate mileage was affected.

Traffic volume increased by 32% for urban and 52% for rural Interstates over 1991-1999. The increase seen on rural Interstates was linear and fairly constant, roughly 5% per year. Urban Interstate traffic volume actually decreased on a year-to-year basis for 1997 compared with 1996 and 1998 compared with 1997. It is likely that this pattern was a reflection of the I-15 reconstruction project rather than being due to a "real" change in urban traffic patterns in Utah.

Rural Interstates. Rural Interstates have been the focus of attention nationally as the effect of increased speed limits are considered, presumably because the highest posted speed limits are on these segments. For rural Interstate segments, annual total crash numbers were roughly stable prior to NMSL repeal and then showed an apparent rise in 1996 and 1997. Intervention time series analysis showed no significant effect associated with the increase in speed limits in mid-1996 on rates of total crashes, fatal crashes, or injury crashes on rural Interstate segments. Additionally, there was no apparent change in the proportion of crashes associated with either fatality or injury. Therefore, in this analysis, the increase in speed limit to 70-75 mph on rural Interstates did not appear to have had an adverse affect on either the occurrence or severity of crashes. In comparison with 65-mph (urban) Interstates, however, the proportion of crashes associated with fatality or injury are markedly higher on rural segments; the overall rates of fatal crashes is also higher, by 2-4 -fold. This is despite the fact that rural segments should intrinsically be the safest part of the Interstate system, although the contribution of higher speed limits is speculative.

Urban Interstates. Annual total crash numbers and rates on urban Interstate segments showed an apparent steady increase for 1992-1995, with a sharp increase between 1995 and 1996, with a subsequent progressive decrease in the ensuing 3 years. Fatality and injury crashes showed similar albeit less pronounced patterns. Intervention time series analysis showed that there was a statistically significant increase in total crash rates associated with the increase in speed limit at the end of 1995, to 60-65 mph on these segments. There was no significant change in the rates of fatality or injury crashes. Also, the proportion of crashes associated with fatality or injury was not visibly affected. It may be tempting to ascribe the increase in total crash rates in 1996 to the increase in posted speed limit. However, the I-15 reconstruction project in urban Salt Lake County was also initiated in 1996 and is a confounding factor. Clearly, road design and traffic flow may be markedly compromised during a major construction project, and an increase in crash frequency based on road status might be predicted. For instance, traffic lanes might be narrowed, traffic diverted, road surfaces sub-optimal, on- and off- ramps may be poorly marked, in unfamiliar locations, with decreased merging distances, etc. Therefore, although the increase in total crash rates is significant, causation cannot be confidently assigned to the increase in posted speed limit. The power of statistical analysis to detect effects on fatality and injury crashes is limited because of small numbers; in particular, fatal crashes on urban Interstate segments are not frequent events, occurring 2-3 times per month statewide. These results do not allow one to confidently conclude that the increase in speed limit to 60-65 mph on urban Interstate segments had an adverse effect on either crash occurrence or severity.

Linkage of Crash File to Hospital File for Interstate Crashes. Linkage of crash file to hospital file was done to evaluate for crash severity. Presumably, a more severe crash would be more likely to result in hospitalization for one or more vehicle occupants, so that annual linkage rates should serve as a reasonable proxy for crash severity. For crashes occurring on both urban and rural Interstate segments, there was moderate year-to-year variation in total number of links between files, and in the linkage rates. Linkages and link rates for urban segments showed no discernable pattern over the study period. Linkage number and rates for rural segments were higher for the single year 1996, the year of speed limit increase. There was a subsequent decrease in these values, and for the last year of the study, both the number of links and the linkage rates for urban segments were the lowest seen at any point during the study period. It does not appear that any effect of the increase in speed limit on crash severity can be identified using record linkage as a proxy for crash severity.

Hospital Charges Associated with Interstate Crashes. Linkage of the crash file to the hospital file made it possible to associate hospital charges with crashes. Hospital charges are higher for more severe injuries in general, so that hospital charges serve as a reasonable proxy for injury and crash severity. Total hospital charges for hospital records that could be linked with crash records were calculated for both urban and rural Interstate segments. The statewide total of all crash-associated hospitalizations was slightly higher for 1996, the year of the speed limit change, than for other years. The mean inpatient charges per link (that is, per hospitalization resulting from a crash) showed no trend over time. Using hospital charges as a proxy for crash and injury severity, therefore, no effect of the increase in speed limit could be identified.

Single-vehicle crashes. Single-vehicle crashes are associated with driver drowsiness, and with monotonous, rural roadways, higher speeds, driving at night, and have a higher fatality and injury rates than crashes in general. (38) Drowsiness-related single vehicle crashes would seem likely of particular importance on rural Interstate segments, that possess many of the above-noted characteristics. The influence of higher speed limits on such crashes is unknown; it has been speculated that higher speed limits might reduce their likelihood since higher travel speed would lead to shorter travel times and hence less time for drivers to become drowsy. A reduction in drowsiness-related crashes has been suggested as a possible benefit of higher speed limits, via this mechanism. The proportion of all crashes, on both urban and rural Interstates, that was of single-vehicle type did not change over the study period. No effect of increased speed limits on single vehicle crashes, and by inference, driver drowsiness, can be observed in these results. Increase speed limits did not have a beneficial effect on single-vehicle crash occurrence by this mechanism.

State Highways

NMSL repeal was followed by an increase in posted speed limit on many non-Interstate highways, although high-speed roadways and Interstate highways are often considered to be more or less synonymous. However, at least for a state like Utah with large areas of sparsely populated land, there are long stretches of rural 2-lane highways that were also eligible for increase in posted speed limit after NMSL repeal. The mileage of such highways in Utah that underwent speed limit increase was roughly twice that of Interstates affected. Also, the total number of crashes, injury crashes, and fatal crashes were comparable between high-speed Interstates on the one hand and rural non-Interstate highways on the other. (The number of crashes on low-speed non-Interstates segments was comparatively high, since these roadways including many heavily traveled urban segments.) Therefore, there is ample reason to examine crash rates on these highways as well. Not all non-Interstate highways were analyzed; only those highways with some segment affected by NMSL repeal (that is, at least some segment with current speed limit of 60 or 65 mph) were selected for analysis.

Categorization of non-Interstate highways was made difficult by the heterogeneous nature of these roadways. Speed limits on these highways are determined by other factors in addition to urban vs. rural nature, including terrain, curve radius, roadway width, etc. A decision was made to analyze crashes on non-Interstate highways after placing each segment in one of three groups: Low-speed (current speed limit < 50 mph), 55 mph (current speed limit 55 mph) and high-speed (current speed limit 60 or 65 mph). Posting of increased speed limits on these highways occurred at various times after NMSL repeal, mostly during calendar year 1997, and was materially complete at the end of that year. Since only high-speed segments underwent speed limit increase, they were of primary interest in this portion of the study, with 55-mph segments useful for comparison. Traffic volume on all three types of non-Interstate highway segments exhibited a progressive increase over the study period.

Crashes on non-Interstate Highways. The annual number of total crashes on high-speed non-Interstate segments showed a gradual increase over time, while the total crash rates progressively decreased. Both the annual number and rates of fatality crashes appeared to increase over the study period. Annual number of injury crashes showed a gradual increase while injury crash rates were roughly stable. Intervention time series analysis showed a significant increase in the rates of fatality crashes on high-speed segments associated with the increase in speed limit to 60-65 mph during 1997. There was no significant change in the rates of total crashes or injury crashes. Also, the proportion of crashes on high-speed segments associated with fatality increased associated with the increase in speed limit. 55 mph segments, where the speed limit was not altered, showed no significant change in rates of total crashes, fatality crashes, or injury crashes, suggesting that the increase in speed limit on high speed segments might have been causative of the increase in fatal crash rates observed. Of note, the total crash rates and injury crash rates were higher for 55 mph segments than for high-speed segments for every year studied, while the fatality crash rates was higher for high-speed segments for every year. This relationship did not change when speed limits were changed. Therefore, the increase in speed limit to 60-65 mph on certain stretches of non-Interstate highways was associated with a significant increase in the rates of fatal crashes, but not of total or injury crashes.

Linkage of Crash File to Hospital File for non-Interstate Highways. Linkage of crash file to hospital file was done to evaluate for crash severity. Presumably, a more severe crash would be more likely to result in hospitalization for one or more vehicle occupants, so that annual linkage rates should serve as a reasonable proxy for crash severity. For crashes occurring on both 55 mph and high-speed segments, there was a moderate variability from year to year in total number of links between files, and in the linkage rates. Linkages and link rates for both 55 mph and high-speed segments showed an increase for the single calendar year 1996, with a decrease seen in subsequent years. It is difficult to ascribe the higher link rates on high-speed segments in 1996 to change in speed limit, because only about 3% of the total segment mileage to be posted with higher speed limit had been so posted by the end of 1996. Also, the change in linkage rates was also seen on 55 mph segments where the speed limit was never increased. Therefore, the increase in posted speed limit cannot be confidently said to have affected the number and rates of non-Interstate highway crashes associated with a hospitalization.

Hospital Charges Associated with Crashes for non-Interstate Roads. Linkage of the crash file to the hospital file made it possible to associate hospital charges with crashes. Hospital charges are higher for more severe injuries in general, so that hospital charges serve as a reasonable proxy for crash severity. Total hospital charges for hospital records that could be linked with crash records were calculated for both 55 mph and high-speed segments. The mean charges per link (charges per crash-associated hospitalization) were higher for 1997 and 1998 than for previous years, for both 55 mph and high-speed crashes. It is possible that the increase in charges per link for high-speed segments indicates that the injuries were more severe during those years. However, this interpretation is confounded by the fact that the mean charges for 55 mph State highways, not affected by speed limit change, was also higher. Therefore, the increase in posted speed limit cannot be confidently said to have affected the hospital charges associated with crashes on non-Interstate highways.

Comparison With Other Studies

Other studies of NMSL repeal have reported variable results. NHTSA's *Report to Congress* (1) purported to show that crash related fatalities increased after NMSL repeal and subsequent speed limit increase. However, this report was a preliminary effort and contained several acknowledged weaknesses, in particular the lack of exposure (traffic volume) data. Also, the individual states that analyzed data for this report all noted that their data were insufficient to provide for definite conclusions. Balkin et al (29) analyzed FARS data and concluded that after NMSL repeal and associated increase in speed limit, 10 of 36 States experienced an increase in rural Interstate fatalities, and 6 of 31 experienced an increase in urban Interstate facilities. It is probably not possible to conclude that the higher posted speed limit caused an increase in fatalities, since it was not reported in the majority of States.

A limited amount of data are available from other individual States. In Virginia, no increase in crash severity on rural Interstates was found subsequent to NMSL repeal, although speed limits were increased by only 5 mph, from 65 to 70 mph. (33) Investigators in Kansas reported results strikingly similar to those of the present study, finding that increased speed limits on urban and rural Interstates did not affect crash occurrence, but increase in speed limit to 65 mph on rural 2-land highways was associated with a statistically significant increase in both crashes and fatal crashes. (34)

Therefore, the results of the current study appear consistent with the limited information currently available, showing no consistent impact of NMSL repeal and speed limit increase on crash occurrence. It is interesting, however, to juxtapose these results with those of studies of the previous increase in speed limits, when rural Interstate speed limits were increased to 65 mph in 1987 (*vide supra*, page 11). Although these studies are not completely consistent either, they are fairly extensive in number, and in aggregate would more strongly suggest that the previous increase in speed limit was associated with an increase in crash occurrence and severity. Why two different 10-mph increases in speed limit might have differing effects on crash occurrence, if they do, is speculative.

Potential Weaknesses

This project is subject to several potential limitations. The period of observation after the speed limit change was fairly short, 3½ years in the case of Interstate Highways and only 2 years in the case of non-Interstate highways, possibly obscuring an effect on crash occurrence and rates. Also, numbers of crashes and particularly fatal crashes for subsets of highways were fairly small, and thus subject to random variation that might have limited statistical power. Importantly, there is no information on the magnitude, or even the occurrence, of any increase in actual vehicle travel speeds related to increase in posted speed limit. Finally, non-random forces were at work during the study period, notably the I-15 reconstruction project in the urban Salt Lake County, with obvious potential effects on crash occurrence.

Possible Explanations for Lack of Effect of Speed Limit Increase on Crash Occurrence

Intuitively, it may seem logical that higher speed limits lead to higher vehicle travel speeds that lead to increased likelihood and severity of crashes. Indeed, there is often an implicit, underlying assumption that vehicle speed is a major determinant of crash likelihood and severity, that speed limits are the major determinant of typical vehicle speeds, and, therefore, that speed limits exert a powerful influence on crash occurrence and severity. However, such an effect was not convincingly demonstrated in the present study. Several explanations for this may be proffered.

Vehicle speed is not the sole determinant of crash likelihood. Vehicle speed is only one of many variables influencing crash occurrence, including road and vehicle factors and prominently, driver behavior, experience, and ability. (47) The effect of increased travel speed may not be sufficiently powerful to detect in the presence of all these other influences. Increased vehicle speed, at least in the range under consideration, may not have a very powerful independent effect on crash likelihood. Speeds in these ranges may well be within safe ranges for vehicles, highways, and typical driver abilities. To put it in graphical terms, if the curve relating crash likelihood to travel speed has a small slope in this speed range, then the effect of speed limit increase may be too small to readily perceive.

Vehicle travel speed is not completely determined by speed limit. Real-world vehicle speed may not increase very much when higher speed limits are posted. Evidence suggests that typical drivers choose travel speeds largely from intuitive understanding of safe and reasonable speeds based on road and weather conditions, etc, as well as the posted speed limits. Further, changes in speed limits do not necessarily have much influence over actual travel speeds. (32, 35) Studies of speed limit changes have shown increments in mean vehicle speed much smaller than the change in speed limit, often only 1-2 mph after a 10 mph increase in speed limit. (9, 19, 25, 32) How much vehicle speed changed on these Utah highways in response to speed limit increase is not known; however, a previous UDOT study reported an increase of only 1.9 mph in median speed when the speed limit on rural Utah Interstates was increased to 65 mph in 1987. (25)

Factors other than vehicle travel speed, specifically variation in speed, may be more important. Speed variation amongst vehicles comprising the traffic stream may indeed have a greater influence on crash occurrence than do either speed limit or vehicle speed per se, as studies have shown. (5-9) If so, then any effect of speed limit change on crash occurrence might depend on whether such change affects speed variation. However, studies have not shown that changes in speed limit have any consistent effect on speed variability, even in cases where the typical vehicle speed actually did increase somewhat. (18, 19, 22) If speed variation is indeed the primary speed-related factor influencing crash risk, then one would probably not predict an increase in crash rates associated with increased speed limit.

Drivers may adapt to higher driving speed over time. There may be a "learning curve" for drivers as they become accustomed to driving at higher speed after a speed limit increase. If so, any impact of increased speeds on crash occurrence may be blunted as drivers become accustomed to the demands of higher travel speed, possibly by increasing follow distance, increased alertness, etc. It is possible that this was seen in this study in the urban Interstate segment crash rates, where crashes increased around the time of increases speed limit posting but then decreased in ensuing years. Other workers have characterized this as a "decay" phenomenon. (25) However, such a decay phenomenon might be difficult to distinguish from the ongoing background decrease in crash rates.

CONCLUSIONS AND RECOMMENDATIONS

Determination of the effect of increased speed limits on crash rates, severity, and type provides useful information for the State of Utah in setting the speed limit on various highway types, following the repeal of NMSL. Several statements may be made about the implications and limitations of this study.

No definitive statement can be made concerning the impact of increased speed limits on crash occurrence or severity. Although analysis of certain highway types did suggest that crash rates might have been affected, no overall pattern emerged. It did not appear that the changes in speed limit following NMSL repeal tended to either increase or decrease crash rates or severity on the highways of highest interest and highest speed limit, namely 75-mph rural Interstates. Instead, adverse effects associated with higher speed limits were found on 65-mph urban Interstates (total crash rates) and on 65-mph rural non-Interstate highways (fatal crash rates).

Further analysis of speed limits vis-à-vis crash occurrence should be done at a regional (multi-State) level rather than a state level. Analyzing larger numbers of crashes over more vehicle miles traveled might give such a study more power to detect any effect of speed limits. Aggregating all data on a nationwide basis may not be very useful, since crash rates and characteristics in the densely populated Northeast region of the US, for instance, likely have little relevance to sparsely populated Western States such as Utah. However, data could be combined from a group of States in the same area of the country; for instance, Wyoming, Nevada, Utah, and Montana have similar climate and highway characteristics.

The effect of a change in speed limit as a single intervention on crash occurrence is difficult to detect. The causation of motor vehicle crashes is complex, and posted speed limit is only one of myriad behavioral and physical variables that influence crash occurrence. It is by no means clear that speed limit is even a relatively powerful variable in this regard. It may be intuitive that higher posted speed limit will lead to higher driving speed, contributing to higher crash rates and severity. However, a 5 or 10 mph increase in posted speed limit by itself may not yield an effect sufficiently large to detect.

Further research aimed at reducing the occurrence and severity of motor vehicle crashes should not be narrowly focused on speed limits. Alterations in speed limit may not be the most powerful way in which to reduce crash rates. Neither does it appear to powerfully influence occurrence and severity of injuries resulting from crashes. Certainly, the observed steady decline in vehicle crash-related fatalities in the United States is one of the greatest success stories in the entire field of injury control. This trend undoubtedly results from multiple causes, and was not visibly interrupted by the increase in speed limit subsequent to NMSL repeal. In the future, investigative energy might be profitably aimed at discovering the root causes of this remarkable phenomenon.

Blanket alteration in speed limits imposed at the National level as a method of reducing crash rates or associated fatalities and fatalities cannot be supported by this study. It is probable that changes in speed limits at the level of specific roadways or locales may be useful in controlling crash rates at specific locations or areas, but such decisions must be made at the State or local level.

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Appendix: Police Crash Description Tools

IF A QUESTION DOES NOT APPLY, ENTER A "-", IF ANSWER IS UNKNOWN ENTER "U", OTHER EXPLAIN IN DESCRIPTION

DI-9 Rev. 1-97

1

TRAFFIC CONTROL
1. Officer or watchman
2. Flagman
3. Traffic Signal
4. Traffic Signal (Flashing)
5. Stop Sign
6. Yield Sign
7. Railroad Gates or Signal
8. Other (Specify)
9. No Control Present
A. Slow or Warning Sign
B. Traffic Lanes Marked
C. No Passing Lanes
D. One-Way Road or Street
E. Construction or Work Area

2

Accident Severity
1. No injury
2. Possible injury
3. Bruises & Abrasions
4. Broken bones or bleeding wounds
5. Fatal

Type of Collision

SEE LIST ABOVE ON BACK OF FRONT COVER

TYPE OF ACCIDENT
1. MV - Pedestrian
2. MV - MV
3. MV - Train
4. MV - Bicycle
5. MV - Animal (Wild)
6. MV - Fixed Object
7. MV - Other Object
8. Overturned
9. Ran Off Roadway - Thru Median

R. Ran Off Road - Right
L. Ran Off Road - Left
A. Other Non-Collision
D. MV Animal (Domestic)

1st Event 16
2nd Event 17
3rd Event 18

15

CONTRIBUTING CIRCUMSTANCES
00 Did Not Contribute
01 Speed Too Fast
02 Failed To Yield Right of Way
03 Drove Left of Center
04 Improper Overtaking
05 Passed Stop Sign
06 Disregard Traffic Signal
07 Followed Too Closely
08 Made Improper Turn
09 Had Been Drinking
10 Under The Influence Of Drugs
11 Eyesight Defective Uncorrected
12 Asleep
13 Fatigued
14 Ill
15 Improper Parking
16 Improper Lookout
17 Failed To Signal
18 Other Improper Driving
19 Brakes Defective
20 Headlight Insufficient or Out
21 Headlights Glaring
22 Other Lights or Reflectors Defective
23 Steering Mechanism Defective
24 Tires Defective
25 Windshield Not Clear
26 Other Defective Condition of Vehicle
27 Hit and Run
28 DUI
29 Non-Collision (Fire)
30 Collision (Fire)
40 Stolen
41 Non-Contact Vehicle Involved
42 Jackknife
43 Downhill Runaway
44 Cargo Loss or Shifted
45 Explosion or Fire
46 Separation of Units
47 Wrong Side of Road
48 Wrong Way on One Way Street
49 Improper Backing
50 Immersion
51 Towed Vehicle
52 Vehicle Rolling in Traffic Lane

PRIME CONTRIBUTOR
VEHICLE #1,3,5 19
VEHICLE #2,4,6 20
SECONDARY CONTRIBUTOR
VEHICLE #1,3,5 21
VEHICLE #2,4,6 22

ALTERED VEHICLE
1. Suspension
2. Body
3. Tinted Windows
4. Other
5. None

VEHICLE #1,3,5 23
VEHICLE #2,4,6 24

ALIGNMENT (ROADWAY CHARACTER) 3
1. Straight and Level
2. Grade Straight
3. Hillcrest Straight
4. Curve Level
5. Curve Grade
6. Curve Hillcrest
7. Dip Straight
8. Dip Curve

WEATHER 4
1. Clear
2. Raining
3. Snowing
4. Fog
5. Dust
6. Mist
7. Sleeting
8. Cloudy
9. Windstorm

SURFACE CONDITIONS
1. Dry
2. Wet
3. Muddy
4. Snowy
5. Icy
6. Oily

5

VEHICLE MANEUVER (DRIVER INTENT)
01. Go Straight Ahead
02. Overtake (Passing)
03. Make Right Turn
04. Make Left Turn
05. Make U Turn
06. Slow or Stop
07. Start in Traffic Lane
08. Start From Parked Position
09. Back
10. Remain Stopped In Traffic Lane
11. Remain Parked
12. Changing Lanes
13. Merge off or onto roadway

VEHICLE #1,3,5 25
VEHICLE #2,4,6 26

ROADWAY CONDITIONS 6
1. Holes or Ruts in Shoulder
2. Holes, Ruts, Bumps in Roadway
3. Loose Material
4. Obstruction Not Lighted (Darkness)
5. Obstruction Not Marked (Daylight)
6. Road Under Construction
7. Roadway Repairs
8. Obstruction - Previous Accident
9. Other - Specify In Remarks

COLLISION WITH OBJECT
OBJECT STRUCK
A. Guardrail
B. Guardrail End Section
C. Utility Pole
D. Sign Post
E. Delineator Post
F. Bridge Culvert or Other Highway Structure
G. Curb
H. Curb or Safety Island
I. Fence
J. Rigid Barrier (Concrete)
K. Crash Attenuator
L. Dirt Embankment/Ditch/Berm (Mountainside)
M. Wild Animal
N. Domestic Animal
O. Snow Embankment
P. Mailbox or Fire Hydrant
Q. Traffic Channelization Device
R. Tree Shrubbery
S. Building Other Structure (Wall)
T. Other

VEHICLE #1,3,5 27
VEHICLE #2,4,6 28

LIGHT 7
1. Daylight
2. Dawn
3. Darkness Street or Highway Not Lighted
4. Darkness Street or Highway Lighted
5. Dusk

DRIVER VISION OBSCURED
1. Not Obscured
2. Rain, Snow, Etc. on Windshield
3. Windshield Otherwise Obscured By Vehicle Load
4. Vision Obscured By Vehicle Load
5. Trees, Crops, Etc.
6. Building
7. Embankment
8. Signboard
9. Hillcrest
10. Parked Vehicles
11. Moving Vehicles
12. Sun or Headlight Glare
13. Other

VEHICLE #1,3,5 29
VEHICLE #2,4,6 30

KIND OF LOCALITY 8
1. Manufacturing/Industrial
2. Shopping/Business
3. Residential
4. School
5. Farms and Fields
6. Open Country
7. Church
8. Playground
9. Railroad Tracks

PAVEMENT SURFACE TYPE
1. Concrete
2. Blacktop (Bituminous)
3. Brick or Block
4. Gravel; Stone
5. Dirt
6. Other

31

VEHICLE #1,3,5 32

Alcohol/Drug Test
1. No Test
2. Blood
3. Breath
4. Other
5. Unknown
6. Refused
7. Post Mortem
8. Drug Scan

VEHICLE #2,4,6 33
PEDESTRIAN 34

ROADWAY FLOW 9
1. Divided Highway (Median Strip)
2. Divided Highway (Guardrail)
3. Divided Highway (Other Barrier or Barrier Type Unknown)
4. Not Physically Divided
5. One Way Traffic
6. Unknown

10 NUMBER OF LANES ON ROADWAY

11 NUMBER OF VEHICLES INVOLVED

Pedestrian/Bicyclist Action
01. Crossing At Intersection - With Signal
02. Crossing At Intersection - Against Signal
03. Crossing At Intersection - No Signal
04. Crossing at Intersection - Diagonally
05. Crossing Not At Intersection
06. Walking In Roadway - With Traffic
07. Walking In Roadway - Against Traffic
08. Standing on Median Island In Crosswalk
09. Other Standing In Roadway
10. Getting On or Off Bus
11. Getting On or Off Other Vehicle
12. Pushing or Working on Vehicle In Roadway
13. Other Working In Roadway
14. Playing in Roadway
15. Coming From Behind Parked Cars
16. Hitching on Vehicle
17. Lying In Roadway
18. Vending In Roadway
19. Other In Roadway
20. Not In Roadway
21. Riding In Roadway With Traffic
22. Riding In Roadway Against Traffic
23. Walking To or from School
24. Walking on Sidewalk
25. Riding on Sidewalk
00 Not Stated

Alcohol/Drug Test Results

Alcohol enter B.A.C.

Drug enter.
D.P. for Drug Scan Positive
D.N. for Drug Scan Negative

VEHICLE #1,3,5 35
VEHICLE #2,4,6 36
PEDESTRIAN 37
PEDESTRIAN 38

WHICH VEHICLE OCCUPIED
1. Vehicle No. 1
2. Vehicle No. 2
O. Other

POSITION IN-ON VEHICLE
Addition Positions In and Outside of Vehicle
50. Sleeper Section of Cab (Truck)
51. Other Passenger In Enclosed Passenger or Cargo Area
52. Other Passenger In Unenclosed Passenger or Cargo Area (Motorcycle)
54. Trailing Unit
55. Riding on Vehicle Exterior
98. Unattended Vehicle
99. Unknown

13	23	33	43
12	22	32	42
11	21	31	41

12	13	NAME 14	ADDRESS	AGE	SEX	SAFE EQUIP	INJURY TYPE	INJURY CAUSE	INJURY AREA	EXTRI-CATION	EJECTION	THROUGH WHAT AREA EJECTED?

PLACE WHERE ACCIDENT OCCURRED

County

COUNTY ______________ [|]

Indicate the county where the accident occurred. Do not abbreviate.

Code the two digit number representing the county using the following list:

01	Beaver	21	Iron	41	Sevier
03	Box Elder	23	Juab	43	Summit
05	Cache	25	Kane	45	Tooele
07	Carbon	27	Millard	47	Uintah
09	Daggett	29	Morgan	49	Utah
11	Davis	31	Piute	51	Wasatch
13	Duchesne	33	Rich	53	Washington
15	Emery	35	Salt Lake	55	Wayne
17	Garfield	37	San Juan	57	Weber
19	Grand	39	Sanpete		

Body Style/Type Code

Enter the body style or type of vehicle: for example, 2-door sedan, sta.wag., pickup, etc. Also put the two-digit code describing the vehicle type in the space provided by using the following codes:

01 Passenger car - regular
02 Passenger car - compact
03 Passenger car & house trailer
04 Passenger car & boat
05 Passenger car & other trailer
06 Passenger car - public owned
07 Pickup or panel
08 Pickup or panel & house trailer
09 Pickup or panel & boat
10 Pickup or panel & other trailer
11 Pickup or panel & public owned
12 Pickup with camper
13 Single Unit enclosed box (Minimum 2 axles & 6 tires)
14 Truck & trailer
15 Truck tractor-Bobtail (power unit only)
16 Tractor & short trailer
17 Commercial Bus
18 School Bus
19 Motorcycle
20 Motorcycle - public owned
21 Motor driven bicycle (scooter or moped)
22 Ambulance - not emergency
23 Ambulance - emergency
24 Ambulance - public owned
25 Farm tractor and/or equipment
26 Special Mobile Equipment (Construction, Fire, UP&L, etc.)
27 Truck & Mobile Home
28 Other, Horse-drawn carriage (plane, etc.)
30 ATV, 3 & 4 wheelers
31 Truck & 2 short trailers (95' total length)
32 Truck & long trailer (77' total length)
33 Tractor - 2 short trailers (trailer up to 28' each)
34 Tractor - 2 trailers (95' total length)
35 Tractor - 2 long trailers (permitted to 105' freeway)
36 Tractor-long trailer-short trailer (98' total length)
37 Tractor - 3 short trailers (permitted to 105' feet freeway)
38 Tractor & long trailer
40 Hit & Run Vehicle
41 Cargo Tank
42 Passenger car w/vehicle in tow
43 Pickup w/vehicle in tow
44 Tractor w/tractor in tow
45 Motorhome
46 Motorhome w/boat or vehicle in tow
47 Flatbed
48 Dump Truck
49 Concrete Mixer
50 Garbage/Refuse
51 Auto Transporter

Safety Equipment

Indicate the types of safety equipment each driver or occupant(s) was using at the time of the accident. Use the following code list:

1 Lap belt used
2 Lap & shoulder belt used
3 Belts not used
4 Belts not installed
5 Child restraints used
6 Air bag inflated with belts
7 Air bag inflated/without belts
8 Helmet worn
9 Eye protection used
0 Helmet & eye protection used
A Shoulder belt only
B Other
C Unknown

Extrication - Fill in appropriate number

0 - Not extricated
1 - Extricated
9 - Unknown

Ejection

1 - Not ejected
2 - Partially ejected
3 - Fully ejected

Description of Cargo

A. General Freight
B. Household Goods
C. Heavy Machinery
D. Motor Vehicles
E. Gases in Bulk
F. Livestock
G. Solids in Bulk
H. Liquids in Bulk
I. Explosives/Hazardous Materials*
J. Refrigerated Foods
K. Empty
L. Other*

*List in accident description

EXAMPLE:

Body Style/Type Code

13 Single Unit Truck
14 Truck and Short Trailer
15 Truck Tractor - Bobtail (Power Unit Only)
16 Tractor & short trailer
31 Truck and 2 Short Trailers
32 Truck and Long Trailer
33 Tractor - 2 Short Trailers
34 Tractor - 2 Trailers
35 Tractor - 2 Long Trailers
36 Tractor - Long Trailer Short Trailer
37 Tractor - 3 Short Trailers
38 Tractor & long trailer

Disposition Of Vehicle Code

1 Towed
2 Impounded
3 Retained by owner/driver
4 Hit and run

*Source of Carrier Name

1 Side of truck
2 Paperwork
3 Driver

Injury Type-Cause Area

Type

Indicate the type of injury suffered in the accident, using these codes:

1 - No injury
2 - Possible injury
3 - Bruises & abrasions
4 - Broken bones or bleeding wounds
5 - Fatal

Cause

Indicate the object that caused the injury using these codes:

1 - Steering Wheel
2 - Dashboard/Windshield
3 - Roof
4 - Other Interior
5 - Motorcycle handbars
6 - Motorcycle gas tank
7 - Exterior vehicle part
8 - External object

Area

Indicate the area of the victim's body that suffered the most severe inury using these codes:

1 - Head
2 - Face
3 - Neck
4 - Chest
5 - Back
6 - Leg(s)
7 - Arm(s)
8 - Torso
9 - Unknown

TYPE OF COLLISION

REV 1-97

01 Opposite directions
Both vehicles straight
Head On

02 Opposite directions
One vehicle straight
One vehicle turning left

03 Same direction
Both vehicles straight
Rear End

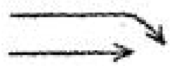
04 Same direction
One vehicle straight
One turning right
Rear End

05 Same direction
One vehicle straight
One turning left
Rear End

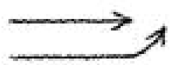
06 Opposite directions
Both straight
Side Swipe

07 Same direction
Both straight
Side Swipe

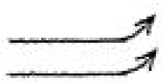
08 Same direction
One vehicle straight
One turning right



09 Same direction
One vehicle straight
One turning left



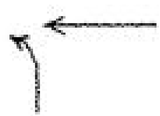
10 Same direction
Both vehicles turning left



11 Both vehicles straight
Approaching at an angle

12 One vehicle straight
One coming from right
turning right

13 One vehicle straight
One coming from left
turning left



14 One vehicle straight
One coming from right
turning left

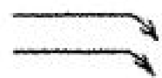
15 Opposite directions
Both vehicles turning left

16 Same Direction
One vehicle turning right
One vehicle turning left

17 Single vehicle

18 Backing

19 Same direction
Both vehicles turning right



20 Approaching at an angle
Both vehicles turning right

21 Approaching at an angle
Both vehicles turning left

22 One vehicle straight
One vehicle making U-Turn

23 Opposite directions
One turning left
One turning right

24 One vehicle straight
One coming from left
turning right

25 Approaching at an angle
One turning left
One turning right

26 One vehicle moving
One vehicle parked