Evaluation of Iowa's 70 mph Speed Limit — 2.5 Year Update

Final Report
January 2009

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16. Abstract

On July 1, 2005, the State of Iowa implemented a 70 mile per hour (mph) speed limit on most rural Interstates. This document reports on a study of the safety effect of this change. Changes in speeds, traffic volume on and off the rural Interstate system (diversion), and safety (crashes) for on- and off-system roads were studied. After the change, mean and 85th percentile speeds increased by about 2 mph on rural Interstates, but speeding was reduced (the number of drivers exceeding the speed limit by 10 mph decreased from 20% to about 8%). In keeping with longer term trends, volumes also increased (about 5%, which was as expected). There was no evidence of traffic shift (diversion) from off-system to on-system (rural Interstate) roads. Daytime and nighttime serious crashes were studied for a period of 14½ years prior to the change and 2½ years afterwards. Due to limitations of data, cross-median crashes were studied for 4½ years before and 2½ years after.

Simple descriptive statistics reveal increases in all crash severity categories for the 2½ year period following the speed limit increase when compared to the most recent comparable 2½-year period prior to the increase. When compared to longer term trends, the increases were less pronounced in some severity levels and types, and for a few severity levels the average crash frequencies were observed to decrease. Few of the changes in crash frequency were larger than the normal year to year variation in these statistics. However, fatal and other serious cross-median crashes increased by relatively larger amounts as compared to expected random variation. Most of this increase was concentrated in the last half of 2005 and represents relatively small numbers of crashes (statistically speaking).

The study also analyzed crash frequencies grouped into six-month periods, revealing similar findings. To more rigorously test for statistical significance in the findings, a generalized regression model was fit to the time series data. The model found that none of the results nor the short term trend were significant at the 95% confidence level, although several results were found to be significant at lower confidence levels.

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EVALUATION OF IOWA'S 70 MPH SPEED LIMIT – 2.5 YEAR UPDATE

Final Report
January 2009

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1. INTRODUCTION

On July 1, 2005, the State of Iowa implemented a 70 mile per hour (mph) speed limit on most rural Interstates. Concern has been expressed that the change may have resulted in a decrease in safety, reflected in an increase in crashes. This report presents the results of a study of the impacts of that speed limit increase, comparing 2½ years of crash data after the speed limit increase to data from two periods: 2½ and 14½ years before the change.

An earlier interim report studied the safety effect of the speed limit change for 18 months prior to and following the speed limit increase. The interim report described a study of how the speed limit change may have affected speeds and safety on other categories of highways in Iowa. These roadways included parallel (to the rural Interstates) routes, expressways, primary highways, urban Interstates, and other rural highways. The study also examined specific portions of the rural Interstates, namely, those within 20 miles of a metropolitan area. The safety performance of I-80 east and west as well as I-35 north and south was examined. These analyses are detailed in the interim project report and summarized in this document.

2. PREVIOUS WORK

There have been a number of studies evaluating the impact of various speed limit increases on crash experience. Fourteen reports covering 12 states were reviewed; in nine states fatal crashes went up, while in the other three there was no change. The following three summaries represent the range of results from these studies:

- Baum et al. (1989) and Baum et al. (1991) reported that in states where the speed limit was increased from 55 to 65 mph on rural Interstates, there was an increase in fatalities on the rural Interstates, while there was no similar trend for states that did not raise speed limits on their rural Interstates.
- Lave and Elias (1994) argued that the states' highway systems should be considered as a whole, rather than as separate entities as was evaluated by other studies. The authors reported that states where speed limits were raised to 65 mph from 55 mph on rural Interstates in 1987 had an overall drop in the statewide fatality rate of 6.15% for the years of 1987 and 1988. States that did not raise their speed limit were reported to have an overall drop in the statewide fatality rate of only 2.62% for the same years. The implication is that drivers may have switched to safer Interstates from lower design class roads with a net increase in highway safety.
- Kockelman (2006), in a study using Washington state data, found a 3% total increase in crash rates and a 24% increase in the risk of fatality on high-speed roads where the speed limit was increased by 10 mph.

3. RESEARCH METHODOLOGY AND RESULTS

The following sections provide a summary of the study methodologies and the results they produced. The following analyses of rural Interstates were conducted:

- Speed and volume analysis
- Crash data assembly and processing
- Descriptive crash analysis
    - Total crash
    - Crashes by severity
    - Cross-median crashes
    - Day-night breakdown of crashes
    - Regional comparison of rural Interstate crashes
- Crash modeling
- Periodic analysis (by six-month periods)

3.1 Speed and Volume

Speed statistics and traffic volumes were computed as reported in the interim report and cover periods 11 months before and 18 months after the speed limit change. Base speed and volume data were provided by the Office of Transportation Data of the Iowa Department of Transportation (Iowa DOT). Speed data were available from August 2004 through December 2006, from the Iowa DOT's system of automatic traffic recorders. These data were processed to provide mean speed, 85th percentile speed, percent exceeding both the speed limit and 80 mph and traffic volumes on the segments.

On the rural Interstates

- the mean and 85th percentile speeds increased about 2 mph and the increases were statistically significant,
- the number of drivers exceeding the speed limit by 10 mph was reduced from 20% to about 8%, and
- traffic volumes increased about 5%.

3.2 Crash Data Assembly and Processing

As an early and ongoing task, crash data were assembled. These data are collected by Iowa law enforcement and assembled, edited, and maintained by the Iowa DOT. For this study, these data were extracted from the archives of the Iowa Traffic Safety Data Service (ITSDS). The data included the period from 1991 to 2007, covering 14½ years before and 2½ years after the speed limit change. Road data were extracted from the Iowa DOT's statewide Geographic Information Management System (GIMS) database.

The procedures to identify Interstate crashes for 1991–1999 involved linking crash information records to point crash locations and using spatial and attribute records to select crashes on the Interstates. Sections with 70 mph speed limits were identified using 2006 GIMS data. These sections were also identified in older versions of GIMS that more closely match the recorded locations of crashes in the before period. Using GIS selection methods, crashes in these areas were selected. Cartographic representation of the highway system in Iowa changed significantly over the time frame of this study. As such, there are many crash locations that do not match perfectly with any one GIS representation of the roadway system. The distance from each crash location to both the nearest rural Interstate segment and to the closest "other type" road was established. Crashes were then classified into four groups:

1. Crashes greater than 100 meters from the Interstate (70 mph sections, or INT70)
2. Crashes within 10 meters of INT70
3. Crashes between 10 and 100 meters of INT70 where distance to the Interstate is *less* than the distance to other roads
4. Crashes between 10 and 100 meters of INT70 where distance to the Interstate is *more* than the distance to other roads

The second and third groupings were classified as study area crashes (those that occurred on segments that now have a 70 mph speed limit. Figure 1 presents the urban and rural Interstates in Iowa. Red segments indicate the sections where the speed limit was raised to 70 mph.

A statewide list of locations of possible/probable cross-median crashes was provided by the Iowa DOT Office of Traffic and Safety (TAS). This list was used in the present study and merged to the list of crashes occurring on segments where the speed limit was changed to 70 mph. While the overall magnitude of cross-median crashes could be significantly different (most likely higher) than the reported number, the methodology used by TAS was applied equally in the before and after periods. Therefore, more confidence should be placed on the magnitude of the change expressed as a percent, rather than the absolute numbers of crashes.

To identify nighttime crashes, a table of sunrise and sunset times was constructed covering the 1991 to 2007 period, based on Ames observations as an average for the state (U.S. Naval Observatory 2008). This table was joined to the crash database and used to select nighttime crashes (crashes before sunrise or after sunset on any given day). The time of day was available on all but 237 of the 30,894 total crashes in the database. Detailed steps of the data collection, preparation, and processing may be found in Appendix A.

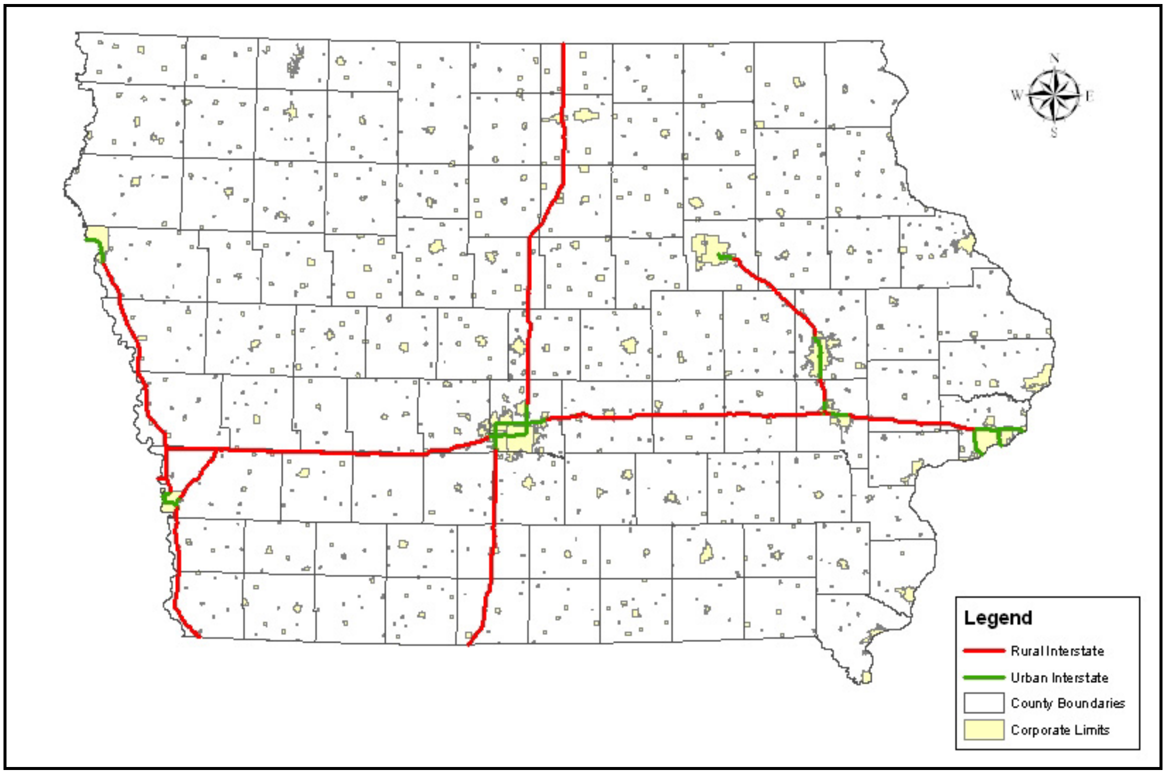

Figure 1. Iowa Interstate study sections

3.3 Descriptive Crash Analysis

Simple measures of crash performance including averages and standard deviations were prepared from the assembled crash data. Daytime and nighttime serious crashes were studied for a period of 14½ years prior to the change and 2½ years afterwards. Due to limitations of data, cross-median crashes were studied for 4½ years prior to the change and for 2½ years afterwards. Table 1 shows increases in all crash severity categories for the 2½ year period following the speed limit increase as compared to the most recent comparable 2½ year period prior to the increase.

Fatal crashes increased on average from 19.2 to 25.2 (an increase in crash frequency of 6.0) per year resulting in a 31.3% increase when compared to the 2½ year before period. However, compared to the average crash frequency over the entire 14½ year before period, fatal crashes increased from 20.7 to 25.2 (an increase of 4.5 or 21.8%). The annual variability (standard deviation) in crash frequencies over the longer period (21.4% of the mean value or about 4.4 crashes per year) is on the order of these changes. Therefore, the changes are similar to what would be expected from random variation in the data. See Figure 2 (mean changes that are large compared to standard deviation are highlighted in gray).

Table 1. Descriptive statistics and results

Rural Interstate crashes before and after 70MPH speed limit		Annual Average for 14.5 years before	Annual Average for 2.5 years before***	Annual Average for 2.5 years after	change ** (compared to 2.5 year avg)	change ** (compared to 14.5 year avg.)	annual standard deviation (14 yrs. before)	% annual standard deviation (14 yrs. before)
Fatal crashes and fatalities	Fatal crashes	20.7	19.2	25.2	31.3%	21.8%	4.43	21.4%
	Fatalities	na	26.4	30.0	13.6%	na	na	
	Cross-median crashes	5.33*	5.20	9.20	76.9%	72.5%*	2.38*	44.6%*
	Night-time crashes	8.28	7.60	9.60	26.3%	16.0%	2.38	28.8%
Serious (fatal plus major injury crashes)	All serious crashes	103	78.8	90.8	15.2%	-12.1%	21.5	20.8%
	Serious Cross-median crashes	8.4 *	9.6	15.2	58.3%	80.0%*	1.41*	16.7%*
	Serious Night-time crashes	42.8	33.6	34.0	1.19%	-20.5%	10.0	23.4%
All crashes	All Cross-median crashes	46.2*	46.8	61.6	31.6%	33.3%*	7.09*	15.3%*
	Night-time cross-median crashes	14.9*	15.2	20.0	31.6%	34.3%*	2.52*	16.9%*

* cross median crash data only available for 4.5 years of the "before" period
** change should be large compared to standard deviation for high statistical confidence
*** most recent previous 2.5 year period beginning in July

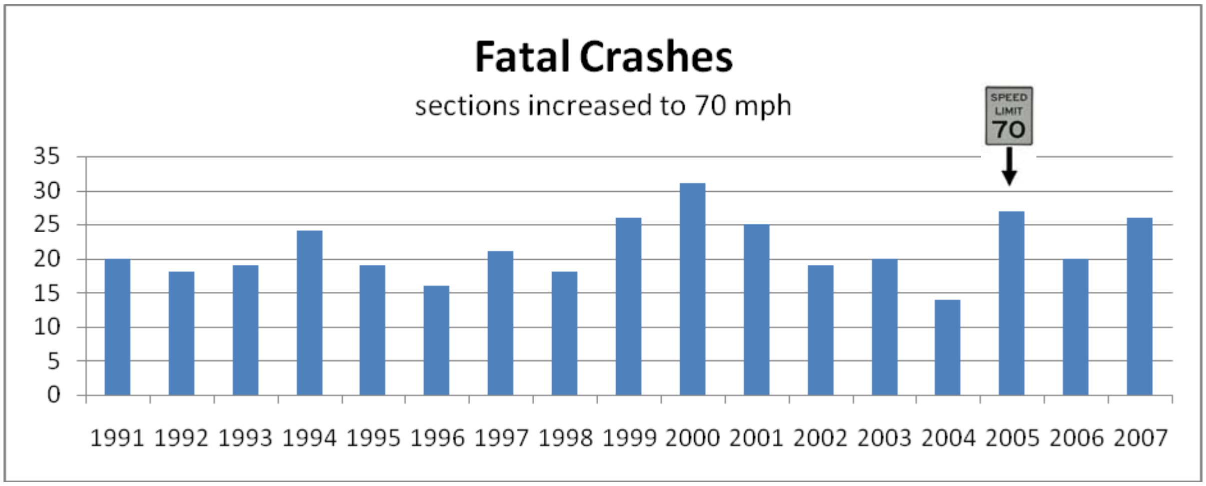

Figure 2. Annual fatal crash history

Serious (fatal and major injury) crashes increased on average from 78.8 to 90.8 per year (an increase of 12.0) resulting in a 15.2% increase when compared to the 2½ year before period. However, compared to the average crash frequency over the entire 14½ year before period, serious crashes *decreased* from 103 to 90.8 (12.2 or a 12.1% *decrease*). The annual variability (standard deviation) in crash frequencies of this severity over the longer period (20.8% of the mean value or about 21.4 crashes per year) is also on the order of these changes (see Figure 3).

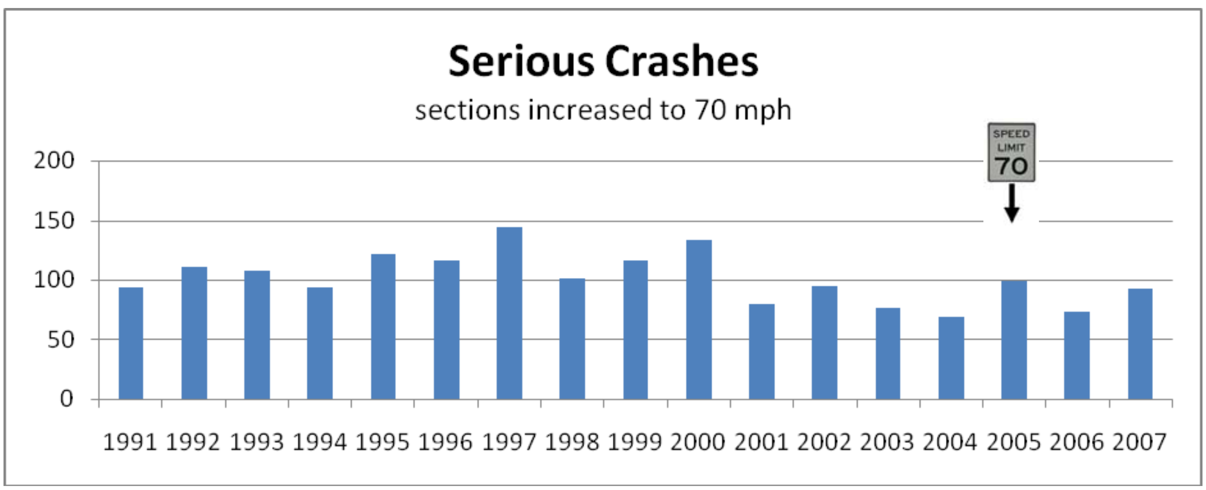

Figure 3. Annual serious crash history

Nighttime fatal crashes increased, although to a lesser extent than all fatal crashes. This type of crash increased on average from 7.60 to 9.60 per year (an increase of 2.0) resulting in a 26.3% increase when compared to the 2½ year before period. However, compared to the average crash frequency over the entire 14½ year before period, fatal crashes increased from 8.28 to 9.60 (an increase of 1.32 or 16.0%). The annual variability (standard deviation) in nighttime fatal crash frequencies over the longer period (28.8% of the mean value or about 2.3 crashes per year) is actually larger than these changes (see Figure 4).

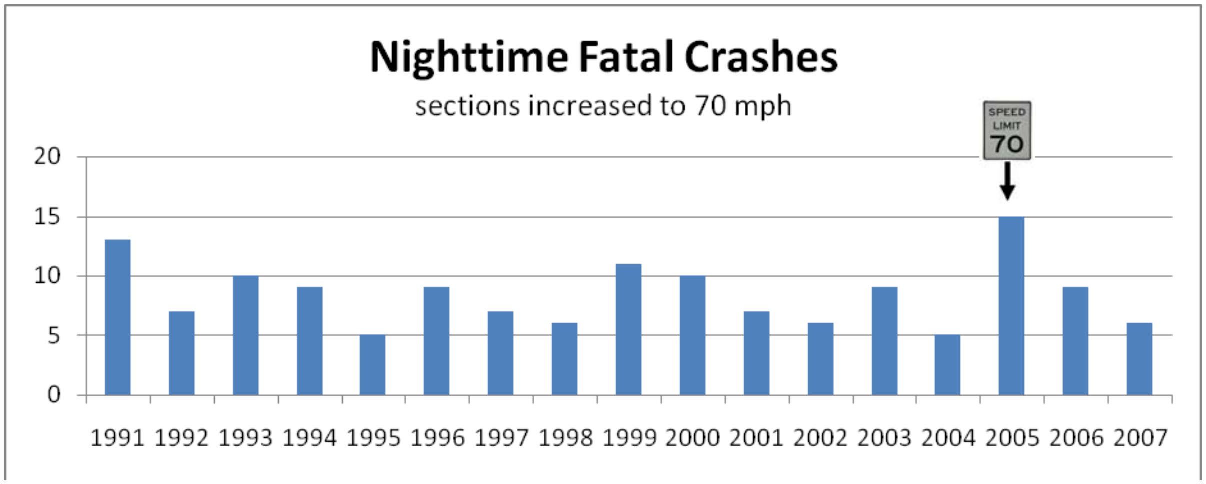

Figure 4. Annual nighttime fatal crash history

Serious nighttime crashes *decreased* compared to the long term trend. This type of crash increased slightly from 33.6 to 34.0 per year (an increase of 0.4) resulting in a 1.2% increase when compared to the 2½ year before period. However, compared to the average crash frequency over the entire 14½ year before period, serious nighttime crashes *decreased* from 42.8 to 34.0 (a reduction of 8.80 or 20.5% reduction). Still, the annual variability (standard deviation) in serious nighttime crash frequencies over the longer period (23.4% of the mean value or about 10.0 crashes per year) is on the order of magnitude of this change (see Figure 5).

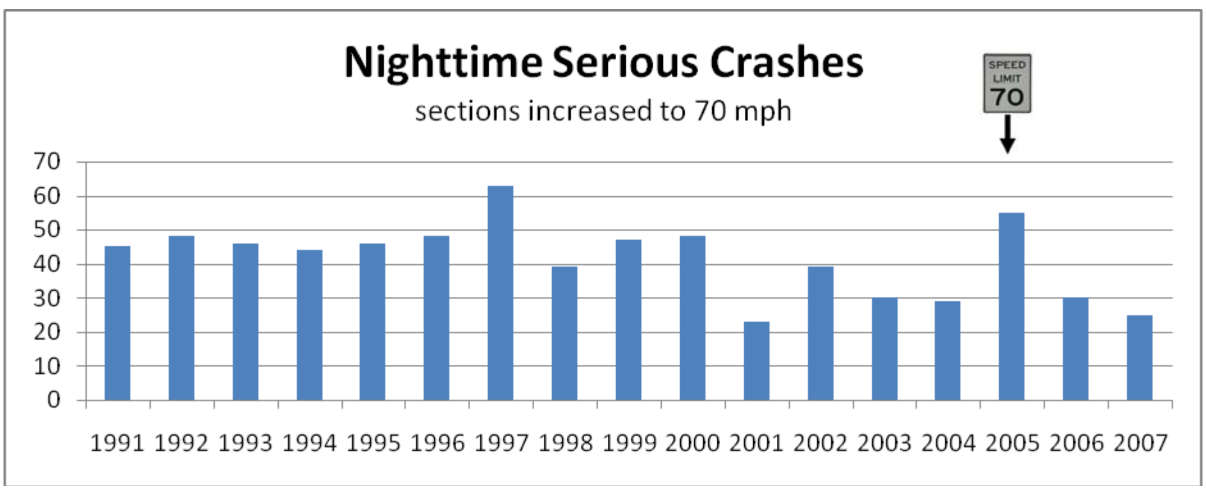

Figure 5. Annual nighttime serious crash history

Fatal cross-median crashes increased on average from 5.2 to 9.2 per year (an increase of 4.0) resulting in a 76.9% increase when compared to the 2½ year before period. When compared to the average crash frequency over the longer 4½ year before period, these crashes increased from 5.33 to 9.2 (an increase of 3.87 or 72.5%). The annual variability (standard deviation) in fatal cross-median crash frequencies over the 4½ year period (44.6% of the mean value or about 2.38 crashes per year) is less than the observed increases, indicating a more significant finding.

However, most of this increase was comprised of fatal crashes occurring during the last half of 2005 and caution should be used as the sample size is small. When 2005 data are removed from the data set, no apparent significant trend can be observed (see Figure 6).

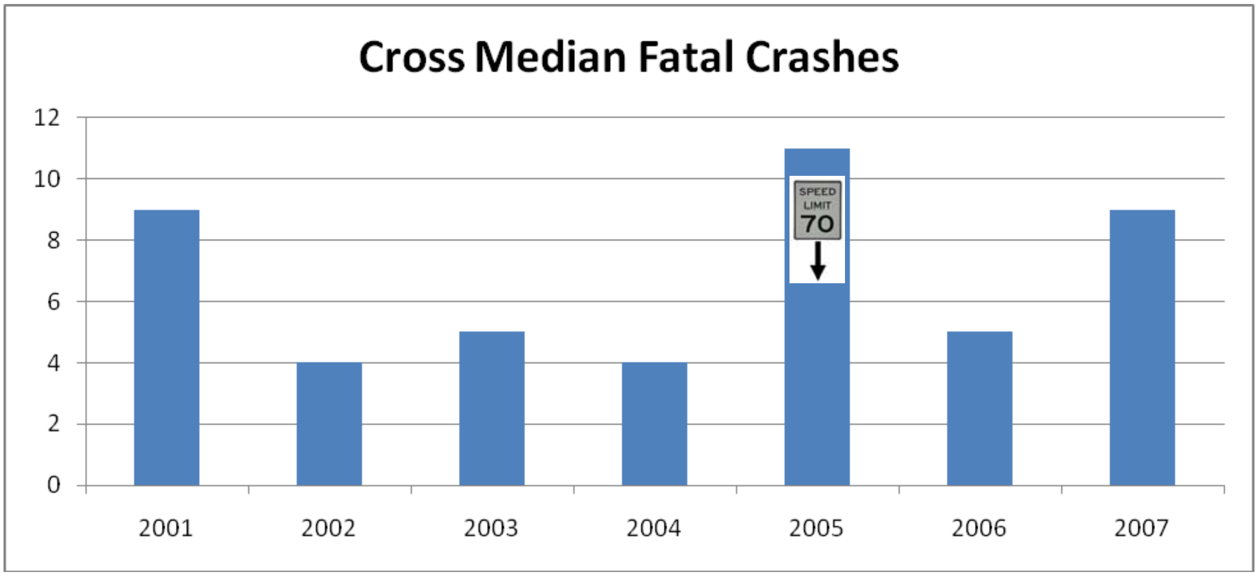

Figure 6. Annual cross-median fatal crash history

Serious cross-median crashes increased on average from 9.6 to 15.2 per year (an increase of 5.6) resulting in a 58.3% increase when compared to the 2½ year before period. When compared to the average crash frequency over the longer 4½ year before period, these crashes increased from 8.4 to 15.2 (an increase of 6.8 or 80.0%). The annual variability (standard deviation) in serious cross-median crash frequencies over the 4½ year period (16.7% of the mean value or about 2.38 crashes per year) is much less than the observed increases, again indicating a more significant finding. However, as was the case for fatal cross-median crashes, most of this increase was comprised of crashes occurring during the last half of 2005 and, again, the sample size is quite small (see Figure 7).

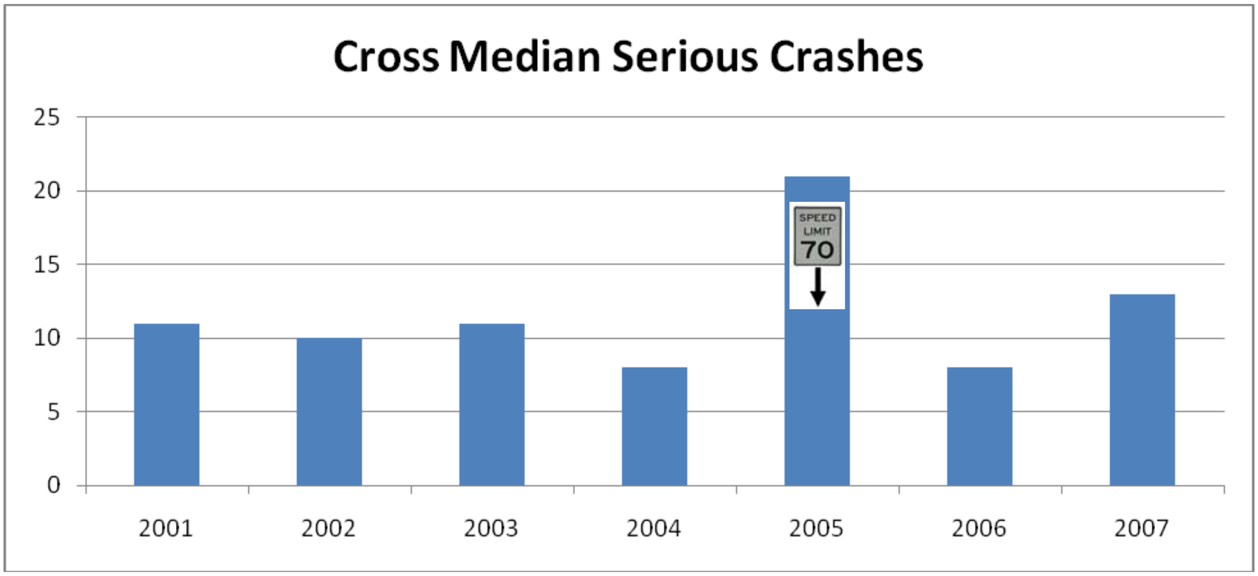

Figure 7. Annual cross-median serious crash history

All cross-median crashes (total of all severity levels) increased on average from 46.8 to 61.6per year (an increase of 14.8) resulting in a 31.6% increase when compared to the 2½ year before period. When compared to the average crash frequency over the longer 4½ year before period, these crashes increased from 46.2 to 61.6 (an increase of 15.4 or 33.3%). The annual variability (standard deviation) in total cross-median crash frequencies over the 4½ year period (15.3% of the mean value or about 7.09 crashes per year) is again much less than the observed increases, again indicating a more significant finding (see Figure 8).

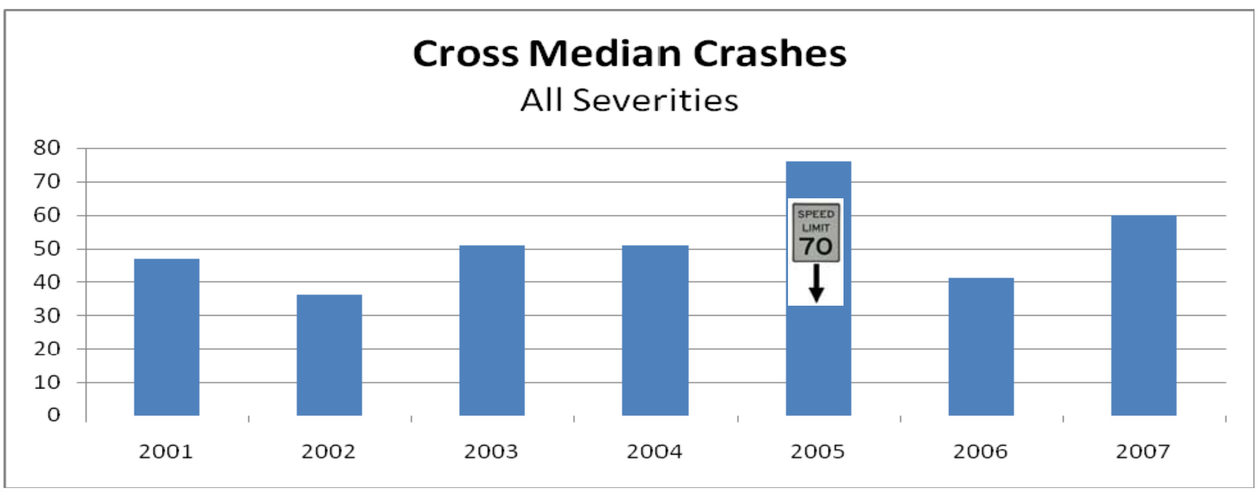

Figure 8. Annual all severities cross-median crash history

All nighttime cross-median crashes (total of all severity levels) increased on average from 15.2 to 20.0 per year (an increase of 4.8) resulting in a 31.6% increase when compared to the 2½ year before period. When compared to the average crash frequency over the longer 4½ year before period, these crashes increased from 14.9 to 20.0 (an increase of 5.1 or 34.3%). The annual variability (standard deviation) in total cross-median crash frequencies over the 4½ year period (16.9% of the mean value or about 2.52 crashes per year) is also much less than the observed increases, once again indicating a more significant finding (see Figure 9).

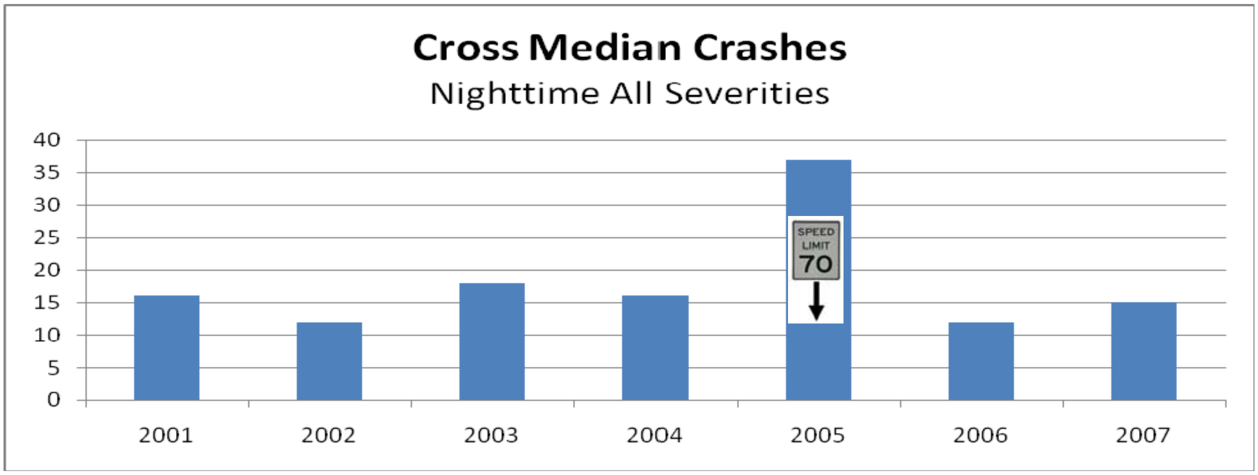

Figure 9. Annual all severities nighttime cross-median crash history

Analysis of off-system (non-rural Interstate and other) roads was conducted earlier during the study, using 18 months of before and after data. Results from that analysis are presented in Appendix C.

3.4 Modeling

To formally test for statistical significance and account for effects of seasonality, volume, and other trends, a generalized linear model was fitted to monthly crash frequency. It was assumed that the number of crashes in a month is distributed as a negative binomial random variable and the canonical log link was used.

Independent variables in the model included the following:

- Time period, with values between 1 (for January 1991) and 204 (for December 2007), time period was introduced into the model as a continuous variable
- The log of monthly traffic volume, expressed in millions of vehicle miles traveled, estimated by "distributing" federal estimates of millions of vehicle miles traveled in each year using information about monthly traffic volume collected by the Iowa DOT
- Month, included as a classification variable, to account for possible differences in crash frequency during the different months of the year
- A break-point or change-point at time period 174, corresponding to the month of July of 2005which allows for a possible change in the slope of monthly crash frequency during 2005

All model parameters were estimated using the method of maximum likelihood which was implemented in SAS Version 9.1. A fixed-effects version of the generalized linear model was fitted, with independent and identically distributed errors as well as a more general version, where errors were allowed to be serially correlated. After accounting for monthly volume and month, there was a negligible amount of left-over structure in the residuals. Thus, results here correspond to the simpler, independent errors version of the model. A more detailed description of the statistical model effort can be found in Appendix B.

The slope of crashes involving minor injuries (severity B) over time increased slightly (about 1%) after the speed limit was increased to 70 mph. Before the speed limit increase, crash frequency was on a very slight negative slope. After the increase, the slope essentially flattened.

Using a standard definition of significance (p=0.05), evidence does not support the conclusion that the increase in speed limit from 65 to 70 mph in rural Iowa Interstates is associated with an increase in the frequency of crashes of severities 1 (fatal), 2 (major or serious injury) or 1 and 2 combined, whether considering all crashes, only nighttime crashes or crashes involving crossing of the median. In fact, in the case of median crossings, there was some slight evidence of an *improvement* in safety (in terms of a slight decrease in the slope of crashes on time) after the increase in speed limit, but this result is suspect given the very low frequency in this type of crashes and the fact that there are few data points available since July of 2005.

Using a relaxed definition of what is significant we find that nighttime crashes of severity 1+2 combined were somewhat affected (negatively) by the speed limit change. The p-value was 0.16 for the hypothesis that the slope in monthly frequency changed after the speed limit changed. *Note: the p-value indicates that if one we were to conclude that there was an increase in monthly frequency after the speed limit change, we would be mistaken with probability 0.16.*

3.5 Periodic (Six-month) Crash Analysis

3.5.1 All Crashes

At the time of this study, crash data were available through 2007. Because the speed limit change took effect on July 1, 2005, 2½ years of after-period data were available. Comparing these data to the 2½ year period immediately preceding the change would compare different parts of the year, when crash frequencies typically differ significantly. For example, the January 2003 to June 2005 period includes three winter seasons but only two holiday seasons (fall), while the after period includes two winters but three holiday seasons. To account for this phenomenon, data were aggregated into January to June (first half) and July to December (second half) periods.

A series of graphs were prepared to illustrate the safety performance both in the first and second halves of the year. Accordingly, for the first-half graphs, 2005 is within the period *before* the change; and for the second-half graphs, 2005 appears in the *after* period (see Figures 10 and 11). The averages reported are for periods of six months. As expected, a difference can clearly be observed in the two time periods, with the second halves of the years having roughly 250 more crashes than the first halves. For each of these stacked bar graphs, the vertical divisions represent the traditional “KABCO” severity categorization of crashes.

- K: fatal
- A: major injury
- B: minor injury
- C: possible injury
- O: property damage only

For the first-half periods, the average number of total crashes before the speed limit change was 697; after the change, the average during these periods was 729 (an increase of 4.6%). In the second-half periods, the average number of total crashes before the speed limit change was 1,089; after the change, the average during these periods was 1,243 (an increase of 14.1%).

It is interesting to note that possible injury crashes (C, or purple category on the graphs) experienced a marked increase in 2007 for both halves of the year.

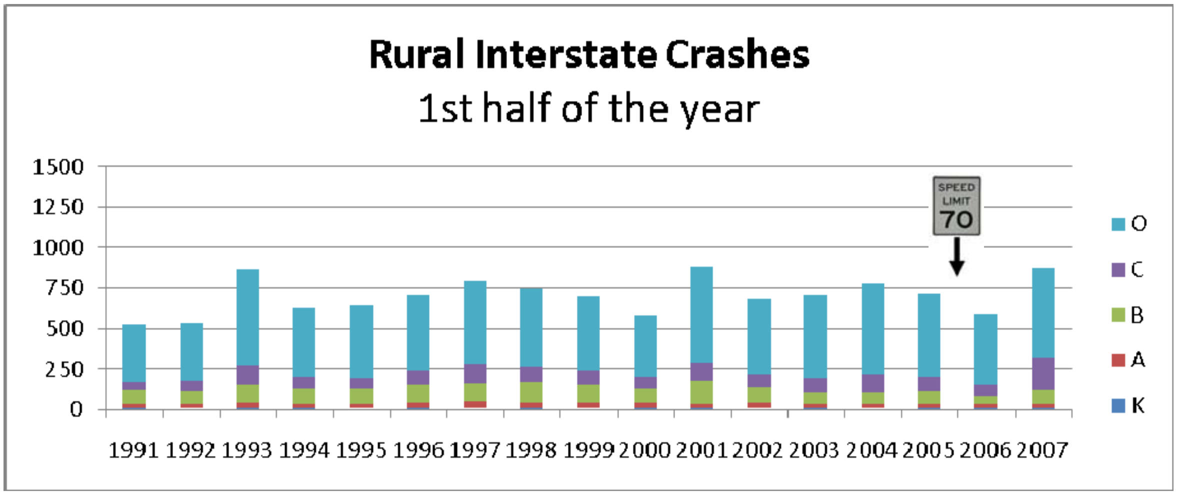

Figure 10. Rural Interstate crashes – first half of year

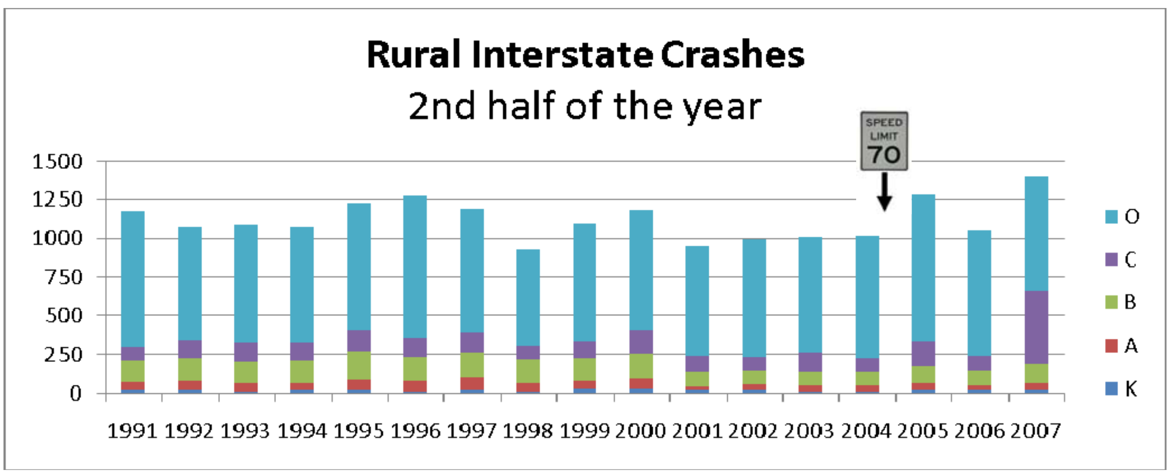

Figure 11. Rural Interstate crashes – second half of year

3.5.2 Serious Crashes

Figures 12 and 13 graphically depict the observation of serious crashes (categories K and A) for all crashes during the study period.

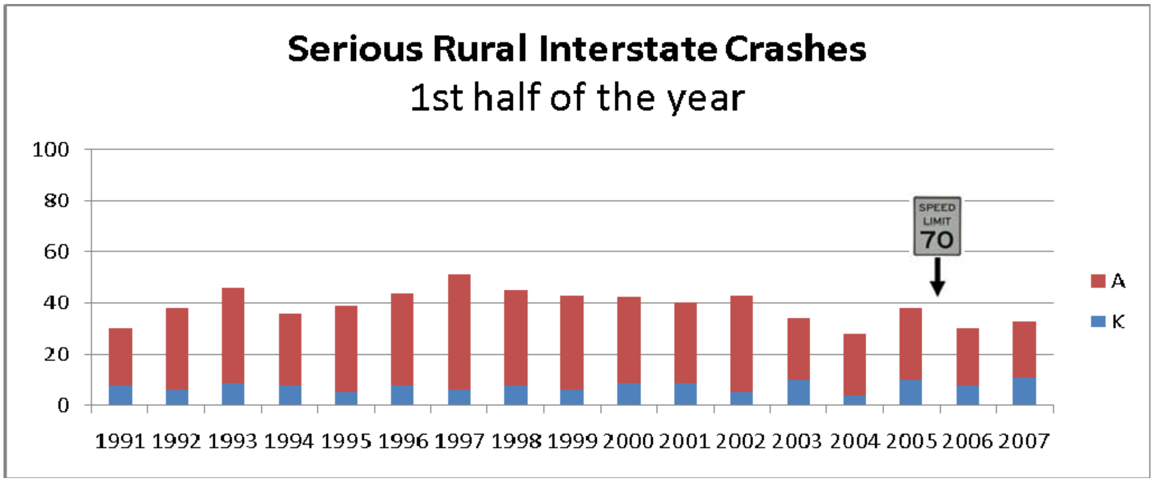

Figure 12. Serious rural Interstate crashes – first half of year

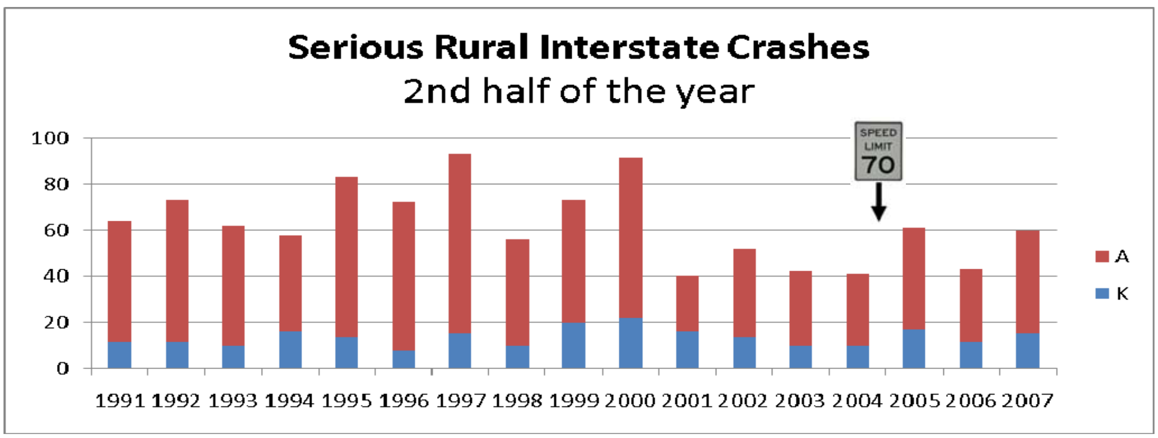

Figure 13. Serious rural Interstate crashes – second half of year

For the first-half periods, the average number of serious crashes before the speed limit change was 39.8; after the change, the average during these periods was 31.5 (a decrease of 20.9%). In the second-half periods, the average number of serious crashes before the speed limit change was 64.3; after the change, the average during these periods was 54.7 (a decrease of 15.0%).

3.5.3 Cross-median Crashes

Cross-median crashes were also analyzed, by severity, as presented in Figures 14 and 15. Cross-median crash data were available only for the period 2001 to 2007. For the first-half periods, the average number of cross-median crashes before the speed limit change was 23.8; after the change, the average during these periods was 18.0 (a decrease of 24.4%). In the second-half periods, the average number of cross-median crashes before the speed limit change was 22.3; after the change, the average during these periods was 39.3 (an *increase* of 76.8%).

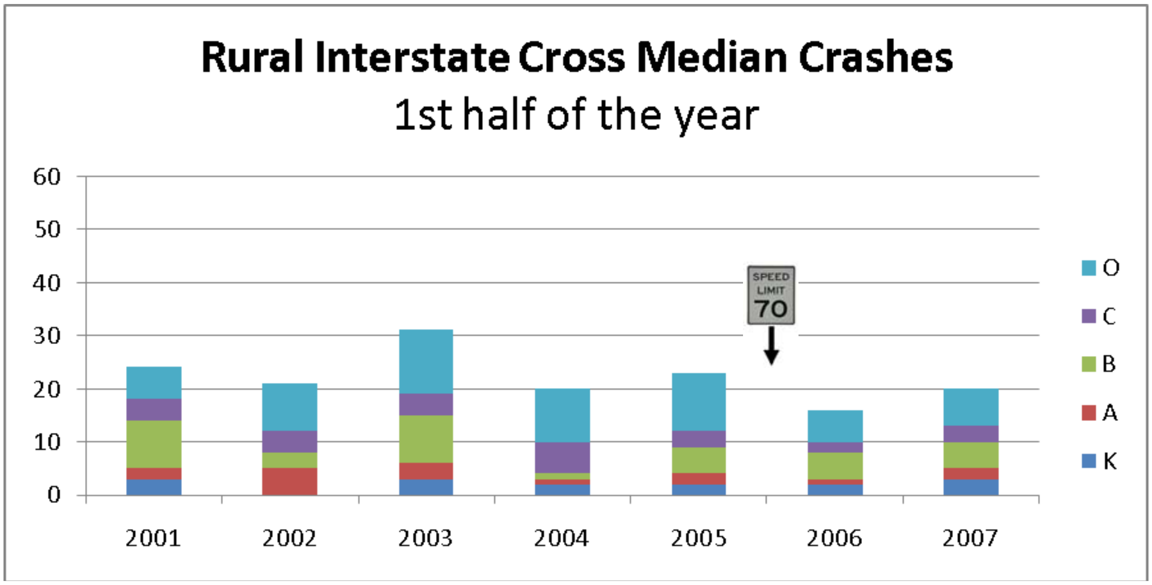

Figure 14. Rural Interstate cross-median crashes – first half of year

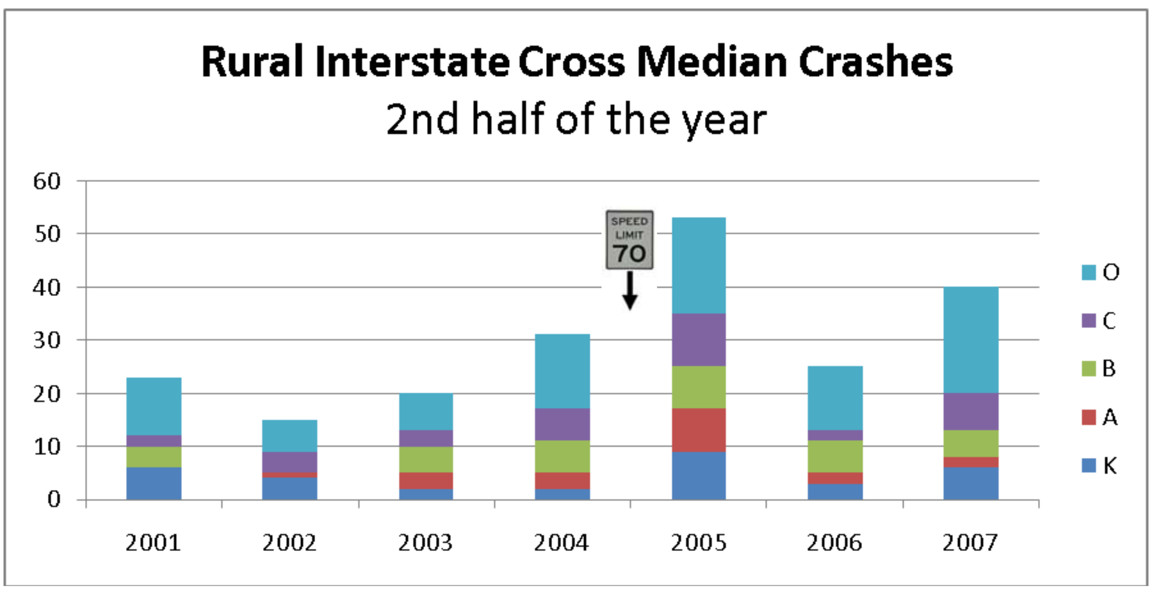

Figure 15. Rural Interstate cross-median crashes – second half of year

Figures 16 and 17 highlight serious cross-median crashes (fatal and major or K+A). The same scale is used for both graphs. For the first-half periods, the average number of serious cross-median crashes before the speed limit change was 2.6; after the change, the average during these periods was 2.0 (a decrease of 22%). In the second-half periods, the average number of serious cross-median crashes before the speed limit change was 3.0; after the change, the average during these periods was 5.0 (an *increase* of 67%). Clearly, caution should be used in interpretation of these results due to the small number of crashes involved.

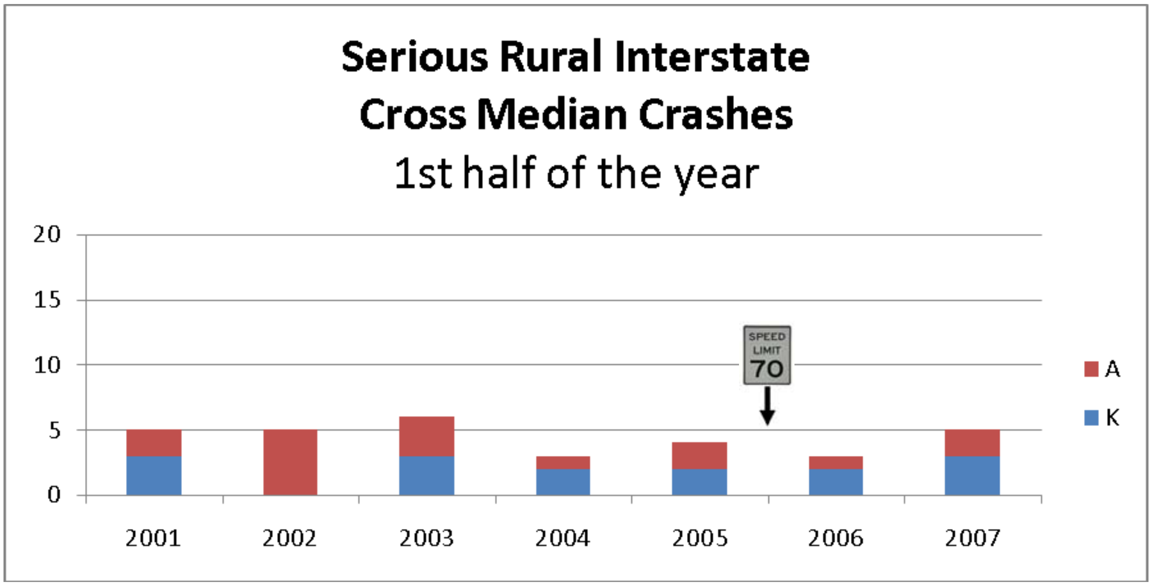

Figure 16. Fatal plus major cross-median crashes – first half of year

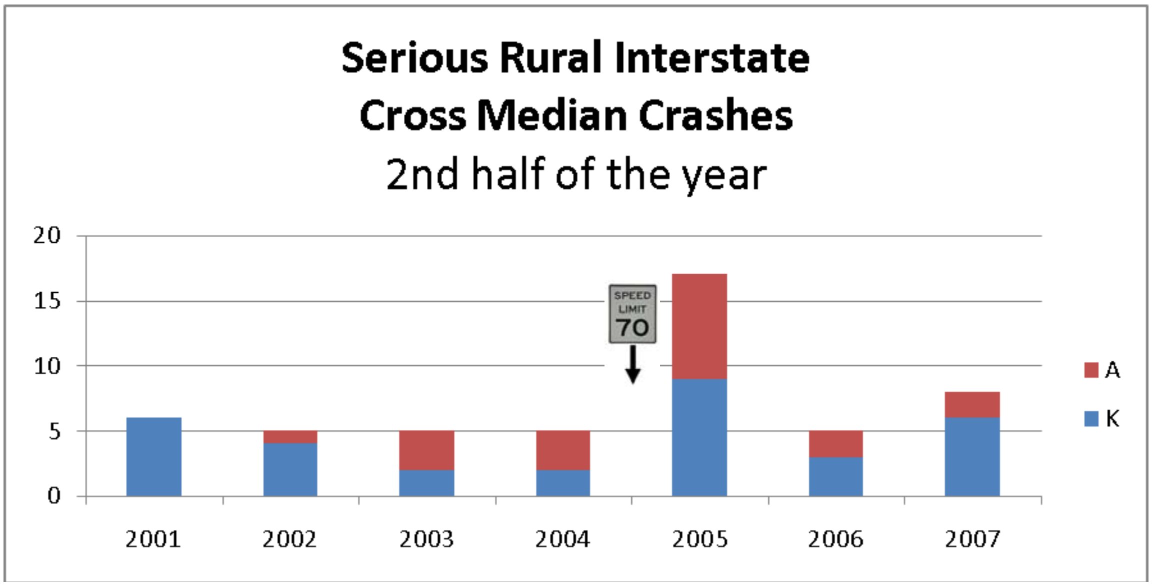

Figure 17. Fatal plus major cross-median crashes – second half of year

3.5.4 Nighttime Crashes

Nighttime crashes were also analyzed, by severity, as presented in Figures 18 and 19. For the first-half periods, the average number of nighttime crashes before the speed limit change was 330; after the change, the average during these periods was 326 (a decrease of 1.3%). In the second-half periods, the average number of cross-median crashes before the speed limit change was 569; after the change, the average during these periods was 651 (an *increase* of 14.4%).

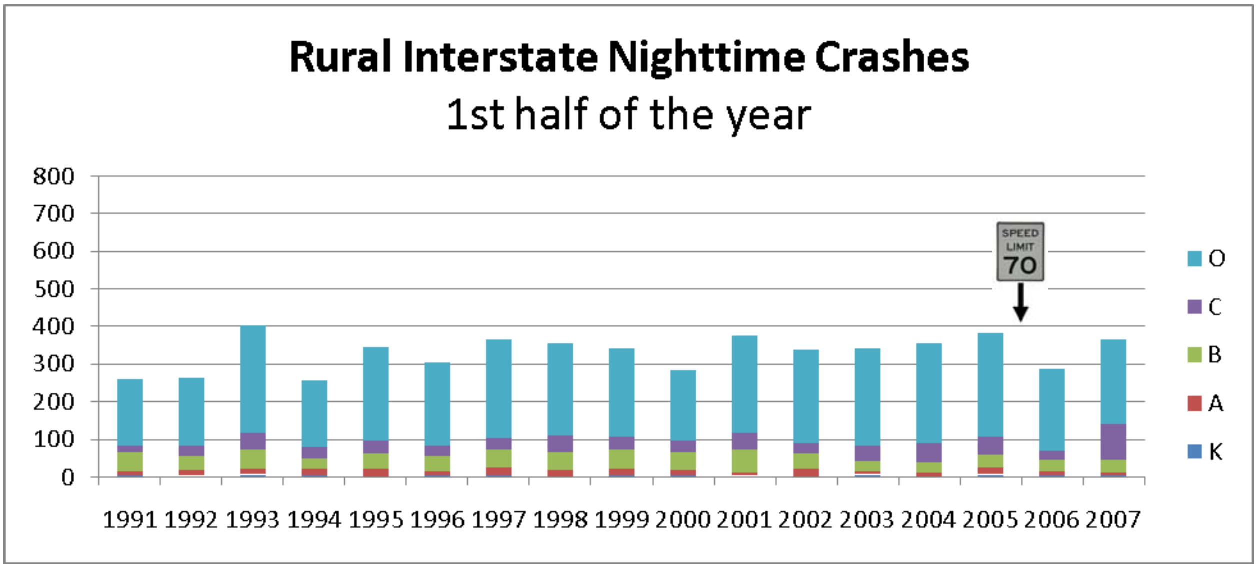

Figure 18. Rural Interstate nighttime crashes – first half of year

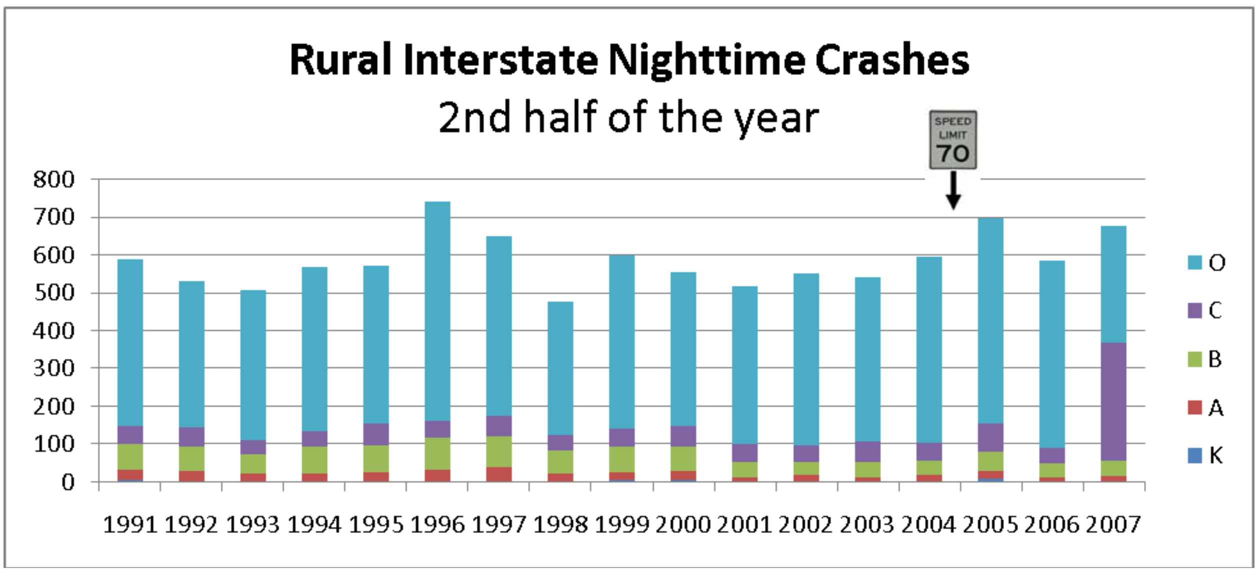

Figure 19. Rural Interstate nighttime crashes – second half of year

3.5.5 Serious Nighttime Crashes

Figures 20 and 21 highlight serious nighttime crashes (fatal and major or K+A). The same scale is used for both graphs. For the first-half periods, the average number of serious nighttime crashes before the speed limit change was 17.4; after the change, the average during these periods was 15.5 (a decrease of 10.9%). In the second-half periods, the average number of serious nighttime crashes before the speed limit change was 25.6; after the change, the average during these periods was 20.3 (a decrease of 20.7%).

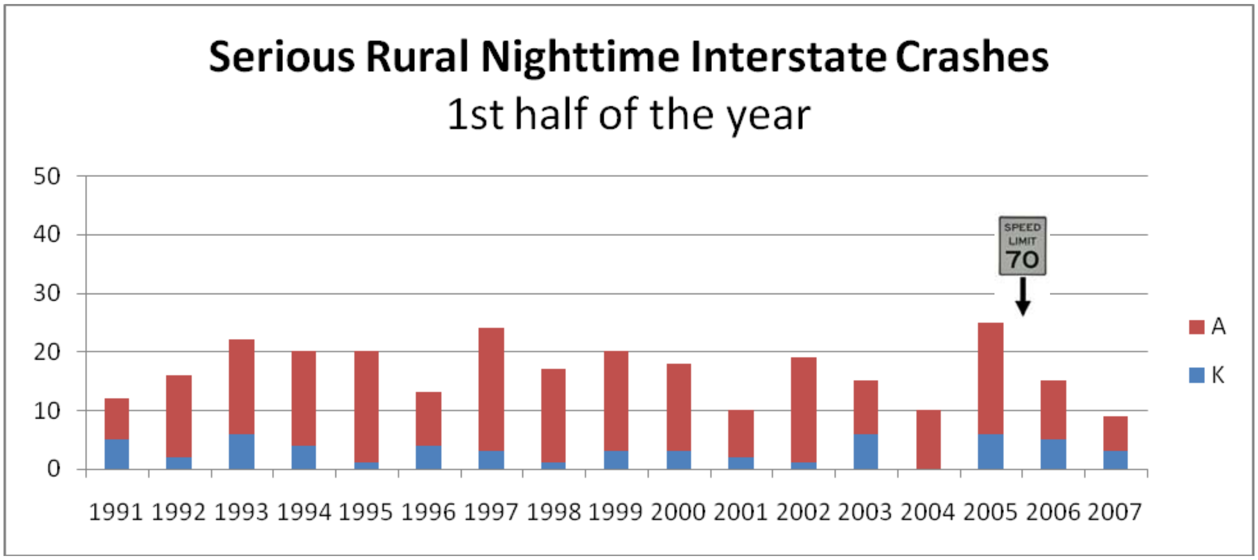

Figure 20. Serious rural Interstate nighttime crashes – first half of year

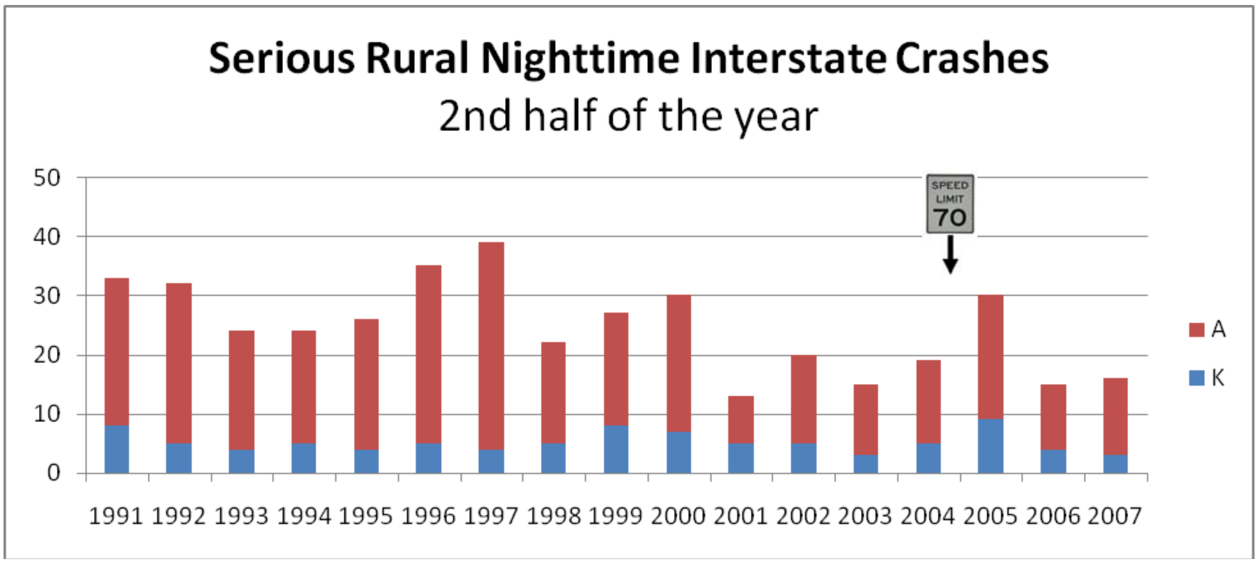

Figure 21. Serious rural Interstate nighttime crashes – second half of year

4. REGIONAL EFFECTS AND RESULTS FOR OTHER ROADS

4.1 Regional Analysis

An analysis by region was also conducted (using 18 months of before and after data). There were increases in most or all categories of crashes on I-35, while on I-80 these same categories remained the same or were lower. On both I-80 segments (Des Moines to Council Bluffs and Des Moines to Iowa City), as well as I-35 north (Des Moines to the Minnesota border), the ratio of fatal to serious crashes was approximately 4%. On I-35 south (Des Moines to the Missouri border), this ratio was about 9%, suggesting that further study into causative and contributing factors may provide insight into possible changes to the roadway environment or to enforcement.

Other (Off-system) Roads

Other roads were studied and reported on in detail in the interim report. Results were based on 18 months of after period data. Speed analyses were based on automatic traffic recorder data from the Iowa DOT covering the period of August 2004 to December 2006.

With respect to routes parallel to and near the 70 mph Interstate segments

- there was no observable shift in traffic to or from the Interstates,
- there was no observable speed spillover from the rural Interstates to the primary parallel routes, and
- on IA-92 (parallel to I-80) the mean and 85th percentile speeds were significantly lower in the after period.

With respect to rural "expressways" (not freeways)

- all categories of crashes experienced a decrease in frequency, although the changes were not statistically significant;
- fatal crashes decreased the most, by more than 18%.;
- both the average and 85th-percentile speeds were lower in the after period, and these changes were not statistically significant; and
- volumes increased by 2%.

With respect to rural "other primary" highways

- the frequency of fatal crashes increased a statistically significant 33% (note that speed limits did not change on these roads), fatal plus major crashes increased approximately 3% (not statistically significant), and total crashes decreased just over 2% (not significant);
- these highways experienced a statistically significant reduction in average and 85th percentile speeds; and
- volumes decreased by 3%.

With respect to rural non-primary highways

- there were small reductions in all crash severity categories, though none of these reductions were statistically significant;
- speed limits were unchanged, and both average and 85th percentile speeds were essentially unchanged in the after period; and
- volumes increased by 7%.

Driver speed adaptation, where a driver who has been on a high-speed facility does not adjust appropriately to a reduced-speed facility, was not observed to occur.

5. SUMMARY

On July 1, 2005, the State of Iowa implemented a 70 mph speed limit on most rural Interstates. This document reported on a study of the safety effects of this change.

Changes in speeds, traffic volume on and off the rural Interstate system (diversion), and safety (crashes) for on- and off-system roads were studied and reported in the interim report for this project, which covered two years of before speed limit change data, and 18 months of after data. After the change, mean and 85th percentile speeds increased by about 2 mph on rural Interstates, but speeding was reduced (the number of drivers exceeding the speed limit by 10 mph decreased from 20% to about 8%. In keeping with longer term trends, volumes also increased (about 5%, which was as expected). There was no evidence of traffic shift (diversion) from off-system to on-system (rural Interstate) roads. Crashes on rural portions of I-35 increased, while those on I-80 remained about the same. On I-35 south of Des Moines, the proportion of fatal to total crashes was more than double that on the other major rural Interstates.

A longer term study was completed for crash analysis on rural Interstates, where the speed limit was increased from 65 to 70 mph. Daytime, nighttime, and cross-median serious crashes were studied for a period of 14½ years prior to the change and 2½ years afterwards. The study found increases in all crash severity categories for the 2½ year period following the speed limit increase when compared to the most recent comparable 2½ year period prior to the increase. It should be noted that the 2½ year period prior to the speed limit change was an historically low period for crash frequencies in Iowa.

Fatal crashes increased on average from 19.2 to 25.2 (an increase of 6.0) per year resulting in a 31.3% increase when compared to the 2½ year before period. However, compared to the average crash frequency over the entire 14½ year before period, fatal crashes increased from 20.7 to 25.2 (an increase of 4.5 or 21.8%). The annual variability (standard deviation) in crash frequencies over the longer period (21.4% of the mean value or about 4.4 crashes per year) is on the order of these changes. Therefore, the changes are similar to what would be expected from random variation in the data.

Serious (fatal and major injury) crashes increased on average from 78.8 to 90.8 per year (an increase of 12.0), resulting in a 15.2% increase when compared to the 2½ year before period. However, compared to the average crash frequency over the entire 14½ year before period, serious crashes *decreased* from 103 to 90.8 (a *decrease* of 12.2 or 12.1%). The annual variability (standard deviation) in crash frequencies of this severity over the longer period (20.8% of the mean value or about 21.4 crashes per year) is also on the order of these changes.

Nighttime fatal crashes increased, although to a lesser extent than all fatal crashes. This type of crash increased on average from 7.60 to 9.60 per year (an increase of 2.0), resulting in a 26.3 percent increase when compared to the 2½ year before period. However, compared to the average crash frequency over the entire 14½ year before period, fatal crashes increased from 8.28 to 9.60 (an increase of 1.32 or 16.0%). The annual variability (standard deviation) in nighttime fatal crash frequencies over the longer period (28.8% of the mean value or about 2.3 crashes per year) is actually larger than these changes.

Serious nighttime crashes *decreased* compared to the long-term trend. This type of crash increased slightly from 33.6 to 34.0 per year (an increase of 0.4), resulting in a 1.2% increase when compared to the 2½ year before period. However, compared to the average crash frequency over the entire 14½ year before period, serious nighttime crashes *decreased* from 42.8 to 34.0 (a *reduction* of 8.80 or 20.5%). Still, the annual variability (standard deviation) in serious nighttime crash frequencies over the longer period (23.4% of the mean value or about 10.0 crashes per year) is on the order of magnitude of this change.

Fatal cross-median crashes increased on average from 5.2 to 9.2 per year (an increase of 4.0), resulting in a 76.9% increase when compared to the 2½ year before period. When compared to the average crash frequency over the longer 4½ year before period, these crashes increased from 5.33 to 9.2 (an increase of 3.87 or 72.5%). The annual variability (standard deviation) in fatal cross-median crash frequencies over the 4½ year period (44.6% of the mean value or about 2.38 crashes per year) is less than the observed increases, indicating a more significant finding. However, most of this increase was comprised of fatal crashes occurring during the last half of 2005, and caution should be used because the sample size is small.

Serious cross-median crashes increased on average from 9.6 to 15.2 per year (an increase of 5.6), resulting in a 58.3% increase when compared to the 2½ year before period. When compared to the average crash frequency over the longer 4½ year before period, these crashes increased from 8.4 to 15.2 (an increase of 6.8 or 80.0%). The annual variability (standard deviation) in serious cross-median crash frequencies over the 4½ year period (16.7% of the mean value or about 2.38 crashes per year) is much less than the observed increases, again indicating a more significant finding. However, as was the case for fatal cross-median crashes, most of this increase was comprised of crashes occurring during the last half of 2005 and, again, the sample size is quite small.

All cross-median crashes (total of all severity levels) increased on average from 46.8 to 61.6 per year (an increase of 14.8), resulting in a 31.6% increase when compared to the 2½ year before period. When compared to the average crash frequency over the longer 4½ year before period, these crashes increased from 46.2 to 61.6 (an increase of 15.4 or 33.3%). The annual variability (standard deviation) in total cross-median crash frequencies over the 4½ year period (15.3% of the mean value or about 7.09 crashes per year) is again much less than the observed increases, again indicating a more significant finding.

All nighttime cross-median crashes (total of all severity levels) increased on average from 15.2 to 20.0 per year (an increase of 4.8) resulting in a 31.6% increase when compared to the 2½ year before period. When compared to the average crash frequency over the longer 4½ year before period, these crashes increased from 14.9 to 20.0 (an increase of 5.1 or 34.3%). The annual variability (standard deviation) in total cross-median crash frequencies over the 4½ year period (16.9% of the mean value or about 2.52 crashes per year) is also much less than the observed increases, once again indicating a more significant finding.

To test the statistical significance of the findings reported above, a generalized regression model was fit to the time series data. In general, the modeling effort found no statistically significant increase in crashes, not accounting for increased traffic volumes, which would further confirm the lack of evidence for statistical increases in crash probabilities. None of the increases observed were found to be statistically significant at the customary .05 (95% confidence) level. However, a number of the increases were found to be statistically significant at lower significance levels, most notably, serious nighttime crashes (at the $p = 0.16$ or what might be considered as an 84% confidence level). There were no statistically significant changes in crash severity. Also, a decreasing trend in minor injury crash frequency (about 1%) before the speed limit change was not observed to continue after the change.

It should be noted that the 2½ year after period is quite short and may not provide an adequate base of data for a reliable statistical analysis. In addition, other factors such as changing economic conditions and high fuel prices may have impacts that mask any speed limit–related changes. Finally, while it is likely changes were due to the speed limit change (as the only significant highway safety–related public policy change in Iowa since 2004 has been the change to 70 mph on rural Interstates), the findings presented herein are necessarily observations of correlation only.

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4. Kockelman, K. (2006). *Safety impacts and other implications of raised speed limits on high-speed roads*. NCHRP Web-Only Document 90 (Project 17-23): Contractor's Final Report.
5. U.S. Naval Observatory. (2008). *Sun or Moon Rise/Set Table for One Year*. http://aa.usno.navy.mil/data/docs/RS_OneYear.php., Astronomical Applications Department of the U.S. Naval Observatory.

APPENDIX A. DATA PROCESSING METHODOLOGY

Crash Data

1. Obtain 1991-2000 crash data from G:_data\Safety_crash\iowa_1979\Statewide19912000
2. Obtain 2001-2007 crash data from G:_data\Safety_crash\iowa_2001\Statewide_04292008 (or latest)

Road Data

1. Open G:_data\Statewide\GIMS\2006\gims_2006_roads.shp (used 2006 because it has the 70mph roads)
2. Query out the Interstates with 70mph speed limit and save the shape file as "2006_70mph.shp"
3. Switch (invert) the selected set and save the shape file as "2006_non70mph.shp"

Procedure to Obtain Interstate Crashes for 1991–1999

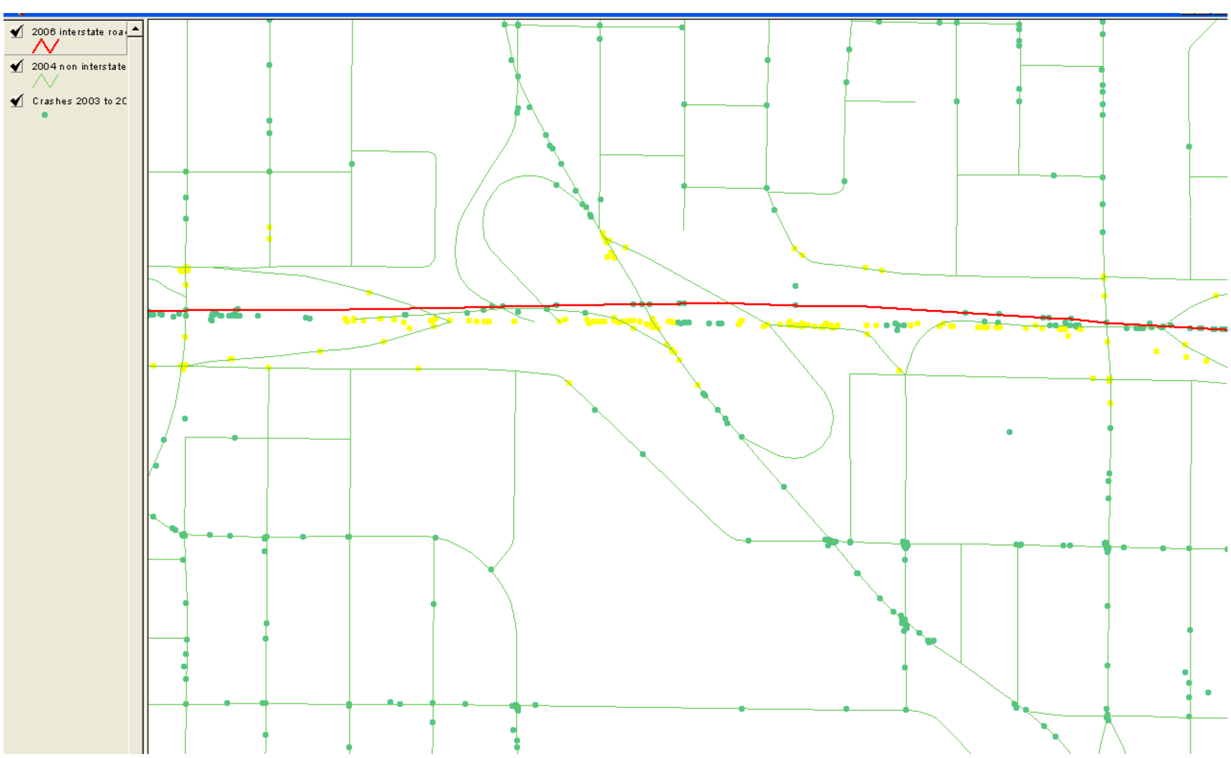
1. Open the A records for 1991-2000 crashes:
   G:_data\Safety_crash\iowa_1979\Statewide19912000\za19xx.dbf
2. QC: Summarize roadclass attribute to see if the 8's or 9's are >500 (this is a QC check – 8s and 9s are unknowns and other. Since most were around this value, 91-99 were deemed OK.
3. Open shp files for 1991-1999 crashes:
   G:_data\Safety_crash\iowa_1979\Statewide19912000\zs19xx.shp
4. Join A records to shp files on crashkey for each year 1991-1999
5. Query out crashes that are on an Interstate and not on a ramp for each year:
   ([Road_class] = 1) and ([Road_char] <> 21) and ([Road_char] <> 22)
6. Save selected crashes for each year as a shape file, e.g.,
   G:_project\70 MPH\2.5_yr_update\Interim files\91_Interstate_crashes.shp
7. Merge all the shp files just created (91 to 99):
   G:_project\70 MPH\2.5_yr_update\91-99_Interstate_crashes
8. Create 3 new fields to 91-99_Interstate_crashes.dbf:
   "Dstto70mph" – Distance to 70 mph section
   "Dstno70mph" – Distance to a non 70 mph section
   "70mphcrash" – Crash on 70 mph section
9. Open: G:_project\70 MPH\2.5_yr_update\2006_70mph.shp
10. Do a spatial join from the 2006_70mph.shp to 91-99_Interstate_crashes.shp
11. Calculate the "Dstto70mph" with the distance provided from the spatial join
12. Remove join
13. Open: G:_project\70 MPH\2.5_yr_update\2006_non70mph.shp
14. Do a spatial join from the 2006_non70mph.shp to 91-99_Interstate_crashes.shp
15. Calculate the "Dstno70mph" with the distance provided from the spatial join
16. Remove join

17. Do a query to find which crashes occurred closer to an Interstate with 70mph speed limit: ([Dstto70mph] < [Dstno70mph])
18. Calculate the “70mphcrash” field with a “1” if the query above is true
19. Examine all crashes that appear to be “in the middle of no-where” and remove those with a ruralurban attribute of U. Leave the others in for system wide analysis

Procedure to Obtain Interstate Crashes for 2000–2008

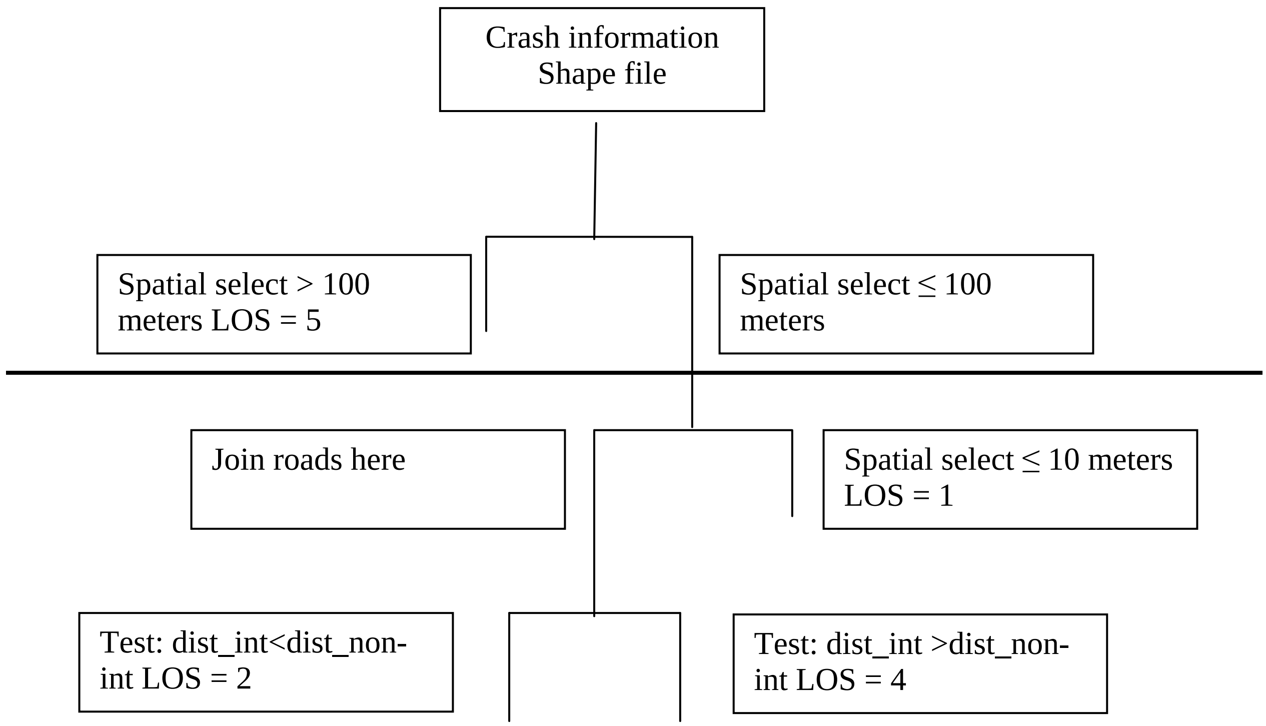
1. Merge all crash shape files 2000-2007 into “Crashes 2000 to 2007.shp”
2. Add a field named LOS to “Crashes 2000 to 2007.shp” to hold an indicator for a 70mph segment crash attribute.
3. Perform spatial joins between “Crashes 2000 to 2007.shp”and “2006_70mph.shp” and “2006_non70mph.shp.” Rename distance to 70mph column as dist_70 and the distance to non70mph column as dist_non70; and query to set the LOS values as:
   a) 1 – if dist_70 <10, calculate LOS =1
   b) 5 – if dist_70 > 100, calculate LOS =5
   c) 2 – if 10 <= dist_70 <= 100, and dist_70 <= dist_non70, calculate LOS =2
   d) 4 - if 10 <= dist_70 <= 100, and dist_70 > dist_non-70, calculate LOS =4*

   *note: the yellow crashes in the figure below are assigned to category 4. This seems to be an urban problem, so can probably ignore for the rural analysis. However, it could have a significant effect on urban Interstate comparisons.



4. To add roadway attributes to the crashes, join the “2006 Interstate roads.shp” to “Crashes 2000 to 2007.shp” using MSLINK to MSLINK_INT.
5. In “Crashes 2000 to 2007.shp”, select all crashes identified as belonging to the Interstate (LOS 1 and LOS 2) and create a new file “2000-2007 Interstate crashes.shp”.
6. Add necessary fields and delete unwanted ones

LOS process flow chart



7. Merge “91-99_Interstate_crashes.shp” to “Crashes 2000 to 2007.shp” to get “91-07_Interstate_crashes.shp”

Cross-median Field

1. Join g:_project\itsds\five_percent\2008\working_v2\prelim_crashes_mvcccm\all\mvcccm2001to2007_sev.shp (statewide cross-median crashes using “SAVER” methodology) to “Crashes 2000 to 2007.shp” on Casenumber.
2. Create new field “xmedian” and populate matching crashes with a 1 (older than 2001 gets a 9999).

Revised Xmedian Procedure

1. Open CTB and VEH tables.

2. Join CTB table to VEH table on crashkey for each year 2001-2007.
3. Join SHP table to VEH table on crashkey for each year (need to have casenumber to match up with the table of 70mph Interstate crashes).
4. Link VEH table to attributes of 91-07_70mph_segment_crashes.shp on casenumber.
5. Select 2001 crashes out of attribute table.
6. Export selected crashes in VEH table. Output: veh_ctb_mvcm_200x
7. Repeat process for each year up through 2007.
8. Append veh_ctb_mvcm_200x.dbf (2001-2007) tables. Output: veh_ctb_mvcm_2001to2007.dbf
9. Select from veh_ctb_mvcm_2001to2007.dbf table: ([V1unitnum] = 1)
10. Create summary table on crash_key. Initdir(max), output: veh1_initdir.dbf
11. Repeat process for remaining vehicles up to ([V1unitnum] = 6)
12. Join the summary initdir tables to the crashes, change Max_Initdir alias' to V*_Initdir.
13. Save as mvcccm2001to2007_sev_v3_use.dbf
14. Add field Seq_cccm to mvcccm2001to2007_sev_v3_use.dbf
15. Link mvcccm2001to2007_sev_v3_use.dbf to veh_ctb_mvcm_2001to2007.dbf
16. Select all records veh_ctb_mvcm_2001to2007.dbf where: ([Seqevents1] = 4) or ([Seqevents2] = 4) or ([Seqevents3] = 4) or ([Seqevents4] = 4)
17. Update Seq_cccm = 1. This indicates that, for at least one vehicle involved in the crash, one of the sequence of events was "crossed centerline/median".
18. Add field Difinitdir.
19. Select all records where ([V1_Initdir] <> [V2_Initdir]) and (([V1_Initdir] <> 9) and ([V1_Initdir] <> 77)) and (([V2_Initdir] <> 9) and ([V2_Initdir] <> 77))
20. Update Difinitdir = 1.
21. Add field Anyinitdir.
22. Select records where ([V1_initdir] <> [V2_initdir])
23. Update Anyinitdir = 1
24. Add field Opinitdir.
25. Select records where ([Difinitdir] = 1) and (([V1_initdir] -[V2_initdir]).abs = 2)
26. Update Opinitdir = 1

27. Open SEV tables for 2001-2007. Append together and join to the mvcccm2001to2007_sev_v3_use.dbf table.

28. Export and save as mvcccm2001to2007_sev_v4_use.dbf

Where Veh=3

1. Select all records where ([Vehicles] = 3) and (([V1_initdir] <> [V2_initdir]) or ([V1_initdir] <> [V3_initdir]))

2. Update Anyinitdir = 1

3. Select all records where ([Vehicles] = 3) and (([V1_initdir] <> [V2_initdir]) or ([V1_initdir] <> [V3_initdir])) and ((([V1_initdir] <> 9) and ([V1_initdir] <> 77)) and (([V2_initdir] <> 9) and ([V2_initdir] <> 77)) and (([V3_initdir] <> 9) and ([V3_initdir] <> 77)))

4. Update Difinitdir = 1.

5. Visually inspect all ([Vehicles] = 3) and ([Difinitdir] = 1) and ([Opinitdir] = 0)

6. If opposite then update Opinitdir = 1.

Where Veh=4

1. Select all records where ([Vehicles] = 4) and (([V1_initdir] <> [V2_initdir]) or ([V1_initdir] <> [V3_initdir]) or ([V1_initdir] <> [V4_initdir]))

2. Update Anyinitdir = 1.

3. Select all records where ([Vehicles] = 4) and (([V1_initdir] <> [V2_initdir]) or ([V1_initdir] <> [V3_initdir]) or ([V1_initdir] <> [V4_initdir])) and ((([V1_initdir] <> 9) and ([V1_initdir] <> 77)) and (([V2_initdir] <> 9) and ([V2_initdir] <> 77)) and (([V3_initdir] <> 9) and ([V3_initdir] <> 77)) and (([V4_initdir] <> 9) and ([V4_initdir] <> 77)))

4. Update Difinitdir = 1.

5. Visually inspect all ([Vehicles] = 4) and ([Difinitdir] = 1) and ([Opinitdir] = 0)

6. If opposite then update Opinitdir = 1.

Where Veh=5

1. Select all records where ([Vehicles] = 5) and (([V1_initdir] <> [V2_initdir]) or ([V1_initdir] <> [V3_initdir]) or ([V1_initdir] <> [V4_initdir]) or ([V1_initdir] <> [V5_initdir]))
2. Update Anyinitdir = 1.
3. Select all records where ([Vehicles] = 5) and (([V1_initdir] <> [V2_initdir]) or ([V1_initdir] <> [V3_initdir]) or ([V1_initdir] <> [V4_initdir]) or ([V1_initdir] <> [V5_initdir])) and ((([V1_initdir] <> 9) and ([V1_initdir] <> 77)) and (([V2_initdir] <> 9) and ([V2_initdir] <> 77)) and (([V3_initdir] <> 9) and ([V3_initdir] <> 77)) and (([V4_initdir] <> 9) and ([V4_initdir] <> 77)) and (([V5_initdir] <> 9) and ([V5_initdir] <> 77)))
4. Update Difinitdir = 1.
5. Visually inspect all ([Vehicles] = 5) and ([Difinitdir] = 1) and ([Opinitdir] = 0)
6. If opposite then update Opinitdir = 1.

Where Veh=6

1. Select all records where ([Vehicles] = 6) and (([V1_initdir] <> [V2_initdir]) or ([V1_initdir] <> [V3_initdir]) or ([V1_initdir] <> [V4_initdir]) or ([V1_initdir] <> [V5_initdir]) or ([V1_initdir] <> [V6_initdir]))
2. Update Anyinitdir = 1.
3. Visually inspect ([Vehicles] = 6) and ([Anyinitdir] = 0)
4. From remaining set review for Difinitdir. From remaining set review for Opinitdir.
5. Repeat for vehicles >6.
6. Add field Xmed_new.
7. It has been determined that ([Opinitdir] = 1) produces the best results in returning crashes that were cross centerline/cross-median.
8. Select all records where ([Opinitdir] = 1)
9. Update Xmed_new=1.
10. Open 91-07_70mph_segment_crashes.shp located in: G:_project\70 MPH\2.5_yr_update
11. Link 91-07_...shp to mvcccm_..._v4_use.dbf on casenumber.
12. Select all records in mvcccm_..._v4_use.dbf where ([Opinitdir] = 1)
13. Update Xmed_new=1 in 91-07_...shp.
14. Select all records in 91-07_...shp where ([Year] < 2001)
15. Update Xmed_new = 9999.

Day/Night Field

1. Using naval observatory sunrise and sunset times per day, 2004-2006, expand the sunrise-sunset data base to 1991-2007.

2. File: G:_project\70 MPH\data_and_analysis\crashes\Interstate_crashes\sample_size_needed\2001-2006_Interstate_crash_data_shapefiles\2001-2006_rural_Interstate_crashes.dbf

3. Queries were used to set nighttime crashes, based on “time” < sunrise or “time” > sunset. Then all queries were re-run to get nighttime crash performance before and after. All 7777 and 9999 times were flagged as 99 in the night crash field

Caveats/Notes

1. Fields which are only available for 2000-2007: LOS

2. Fields which are only available for 2001-2007: Locfstham, Majinjury, Mininjury, Possinjury, Unkinjury

3. Fields which are only available for 2002 (July)-2007: Numlanes, AADT (and these are for a single year, 2006)

4. Time of day (Time) invalid for 237 of the 30,894 records (coded as 7777 or 9999)

5. Toccupants invalid for 433 of the 30,894 records (coded as 777 or 999)

Summary QC Stats

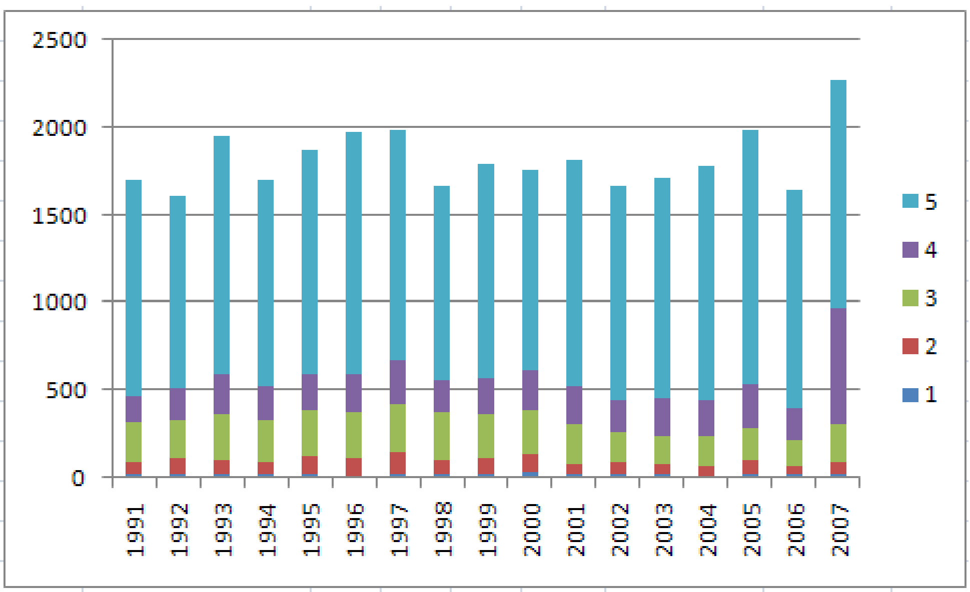
Cseverit	Count
1	363
2	1361
3	3810
4	3950
5	21410

Fatalities	Count
0	30531
1	289
2	51
3	17
4	3
5	2
9	1

Injuries	Count
0	21555
1	6243
2	1976
3	594
4	303
5	122
6	54
7	20
8	12
9	3
10	4
11	2
12	1
13	2
14	1
16	1
20	1

Vehicles	Count
0	3
1	20795
2	8997
3	843
4	168
5	55
6	15
7	6
8	2
9	1
10	2
11	1
15	1
17	2
20	2
28	1

Count of CSEVERITY	Column Labels					
Row Labels	1	2	3	4	5	Grand Total
1991	20	74	230	140	1237	1701
1992	18	93	219	189	1088	1607
1993	19	89	253	229	1363	1953
1994	24	70	237	199	1167	1697
1995	19	103	271	206	1272	1871
1996	16	100	266	209	1385	1976
1997	21	123	277	253	1311	1985
1998	18	83	278	186	1101	1666
1999	26	90	255	198	1225	1794
2000	31	102	250	229	1145	1757
2001	25	55	226	222	1289	1817
2002	19	76	172	175	1228	1670
2003	20	56	162	217	1260	1715
2004	14	55	171	203	1343	1786
2005	27	72	181	254	1458	1992
2006	20	53	148	174	1244	1639
2007	26	67	214	667	1294	2268
Grand Total	**363**	**1361**	**3810**	**3950**	**21410**	**30894**



APPENDIX B. STATISTICAL MODELING

We investigated whether the adoption on July 1, 2005, of the 70 mph speed limit in rural Iowa Interstates is associated with an increase in the frequency of crashes on those roadways.

We focused on crashes classified as being of severity 1 (involving fatalities), 2 (involving major injuries) or 3 (involving minor injuries). Because there are few fatal crashes in any given month, we also considered a combined crash category involving both fatal and major injury crashes. Within this last group, we analyzed total frequency (crashes occurring at any time), nighttime crash frequency, and frequency of crashes in which the vehicle crossed the median.

Summary of Results

The slope of crashes involving minor injuries (severity 3) on time increased slightly (about 1%) after the speed limit was increased to 70 mph. Before the speed limit increase, crash frequency was on a very slight negative slope. After the increase, the slope essentially flattened.

Using a standard definition of significance (p=0.05), we found no evidence that the increase in speed limit from 65 to 70 mph on rural Iowa Interstates is associated with an increase in the frequency of crashes of severities 1, 2 or 1 and 2 combined, whether we considered all crashes, only nighttime crashes, or crashes involving crossing of the median. In fact, in the case of median crossings, we found some slight evidence of an *improvement* in safety (in terms of a slight decrease in the slope of crashes on time) after the increase in speed limit, but this result is suspect given the very low frequency of this type of crash and the fact that we have few data points available since July of 2005.

Using a relaxed definition of what is significant (30% –35%) we find that nighttime crashes of severity 1 and 2 combined were somewhat affected (negatively) by the speed limit change. The p-value was 0.16 for the hypothesis that the slope in monthly frequency changed after the speed limit changed. The p-value means the following: if in a test of hypothesis we were to conclude that there was an increase in monthly frequency after the speed limit change, we would be mistaken with probability 0.16.

Methods

We fitted a generalized linear model to monthly crash frequency. We assumed that the number of crashes in a month is distributed as a negative binomial random variable and used the canonical log link.

Independent variables in the model included

- time period, which took on values between 1 (for January 1991) and 204 (for December 2007). Time period was introduced into the model as a continuous variable.
- the log of monthly traffic volume, expressed in millions of vehicle miles traveled. We estimated monthly traffic volume by "distributing" federal estimates of millions of vehicle miles traveled in each year using information about monthly traffic volume collected by the Iowa Department of Transportation. From these Iowa data, we estimated which proportion of

the annual volume is observed in any one month, on average. The plot shown in Figure 1 below corresponds to the distribution (over several years of data collection) of the proportion of traffic observed during each month of the year.

- month, included as a classification variable, to account for possible differences in crash frequency during the different months of the year. We used the month of December as the reference month.
- a break-point or change-point at time period 174, corresponding to the month of July 2005. This change-point in the model allows for a possible change in the slope of monthly crash frequency on time period, between the 1991–2005 and the 2005–2007 periods.

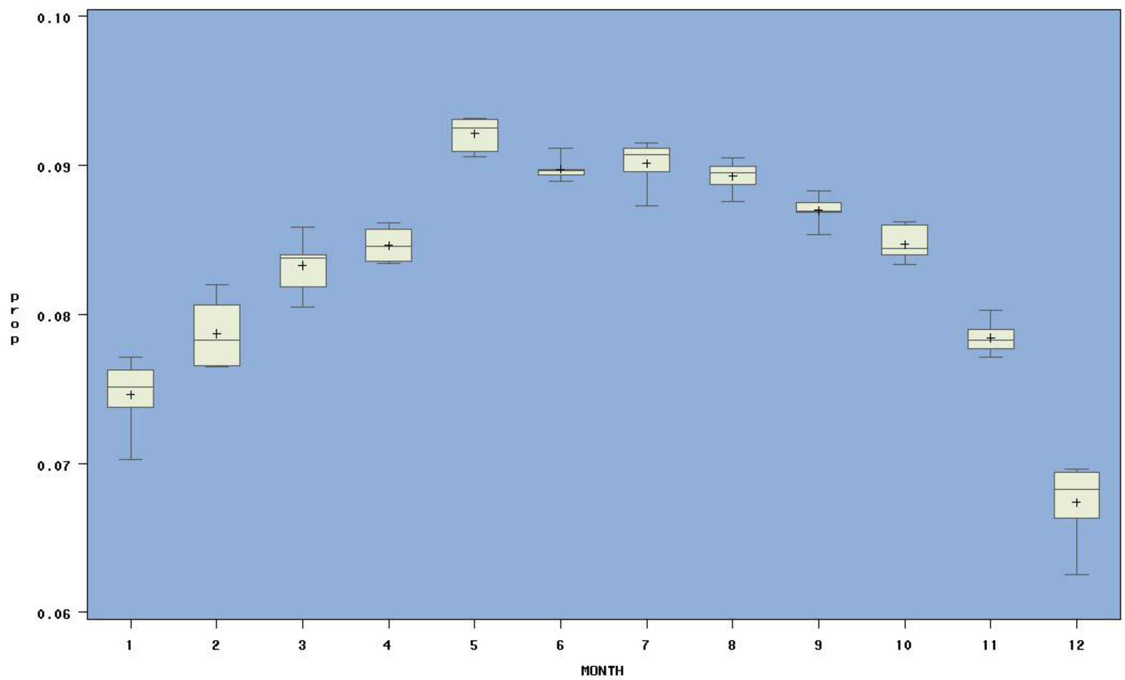


Figure B.1. Distribution of traffic volume over the 12 months of the year; each box represents the distribution over six years of information, of the estimated monthly proportion of annual volume

The parameter associated with the change-point effect is the critical parameter in the model. If we estimate this parameter to be significantly different from zero, then we have some evidence to suggest that the increase in speed limit is associated with a change in crash frequency.

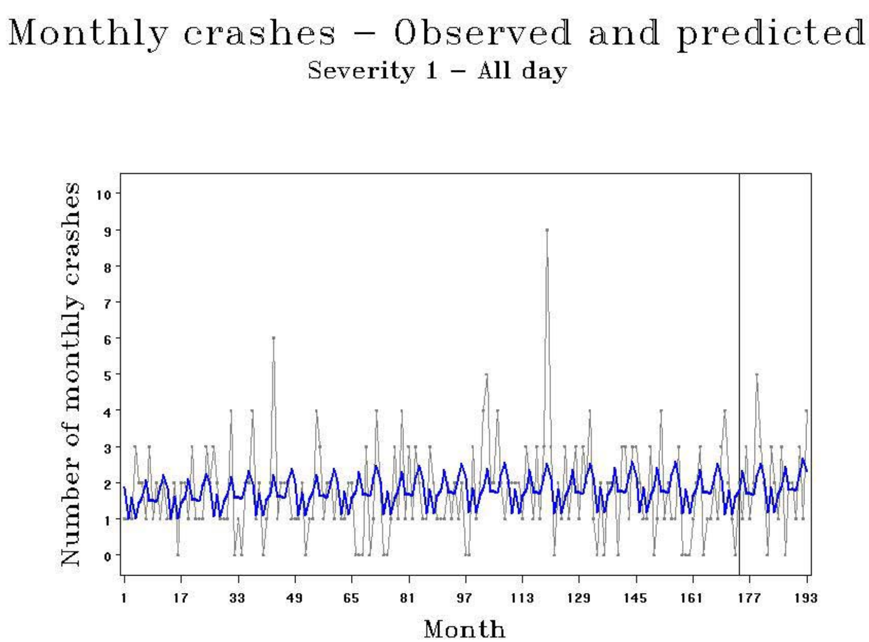
Because we have no control data in this study however, we cannot conclude that a change in the slope of crash frequency on time is attributable to the speed limit increase. It may be the case that some other factor is causally associated with the change in safety and that the speed limit just happened to be increased at the same time at which this other unobserved factor was having an effect. Thus, results must be interpreted with caution given the limitations of the observational data.

We estimated all model parameters using the method of maximum likelihood which we implemented in SAS Version 9.1. We fitted a fixed effects version of the generalized linear model with independent and identically distributed errors and also a more general version, where errors were allowed to be serially correlated. We found that after accounting for monthly volume and month, there was a negligible amount of left-over structure in the residuals. Thus, results here correspond to the simpler, independent errors version of the model.

Results

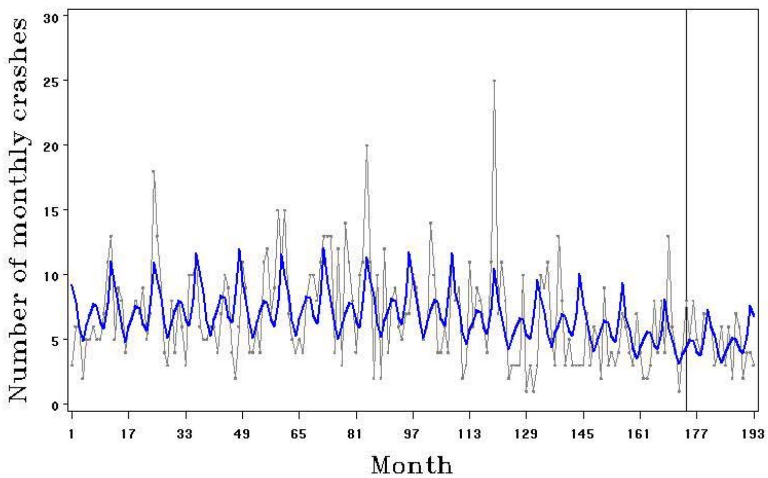
As one might expect, we found that log monthly volume and month were statistically significant effects. The frequency of monthly crashes tended to increase when traffic volume increased and spring and fall months tended to be significantly safer than winter or summer months. Overall, summer months tended to be somewhat safer than winter months.

Figures below show the observed monthly crash frequencies and the monthly crash frequencies estimated from the statistical model. In each figure, the vertical line at time = 174 represents July, 2005. This was the time when the speed limit increased from 65 to 70 mph on rural Iowa Interstates.



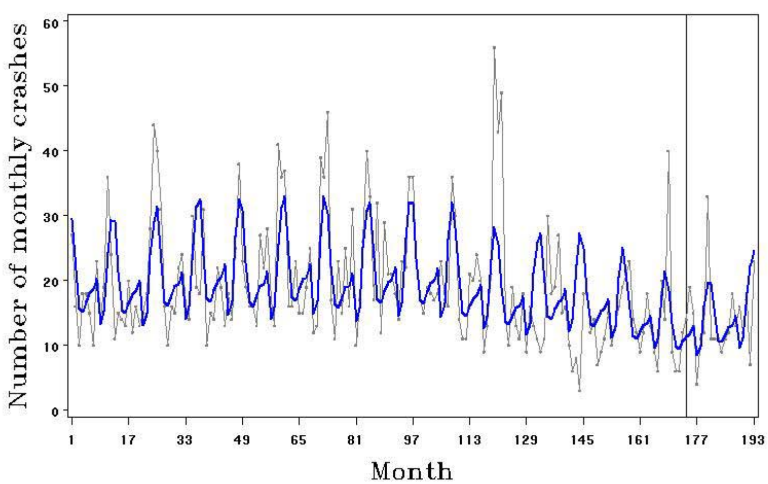
Monthly crashes – Observed and predicted

Severity 2 – All day

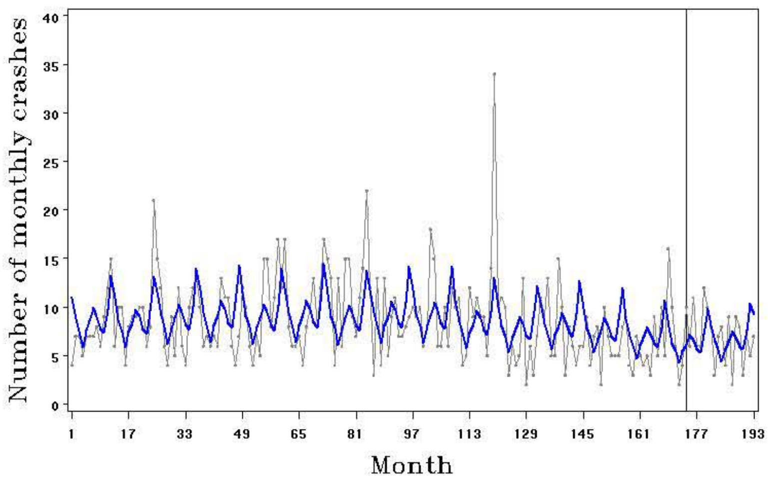


Monthly crashes – Observed and predicted

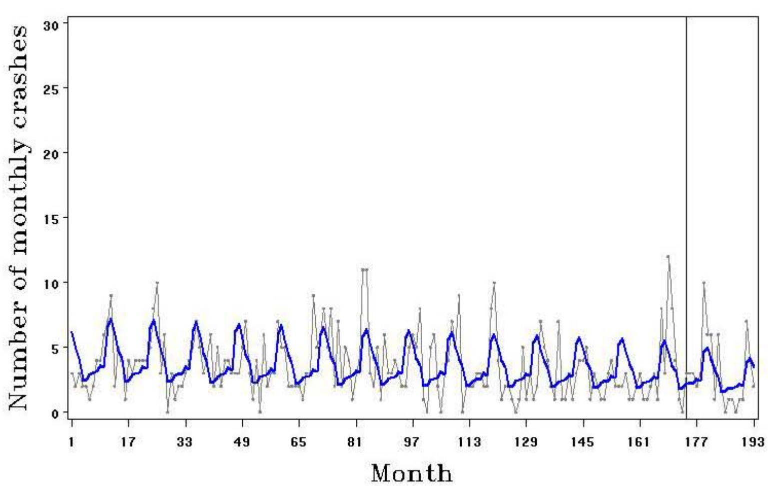
Severity 3 – All day



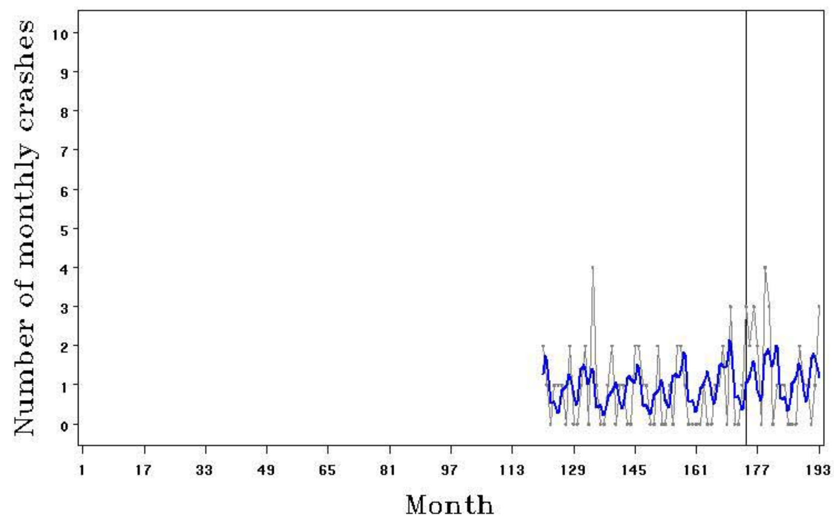
Monthly crashes – Observed and predicted
Severities 1 and 2 – All day



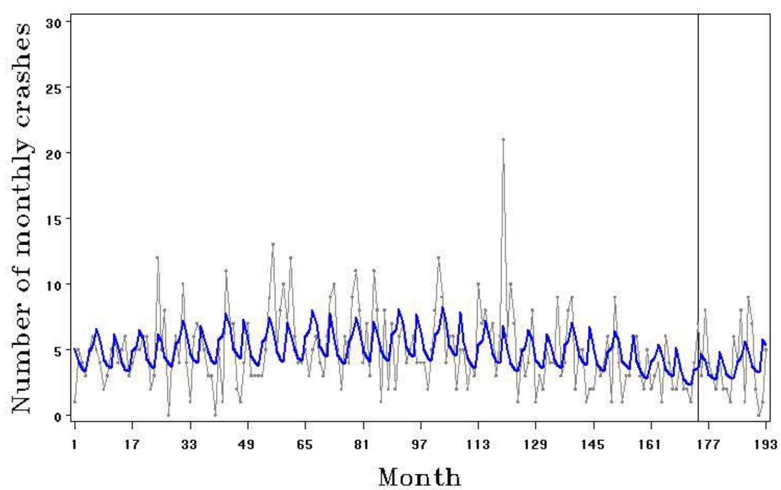
Monthly crashes – Observed and predicted
Severities 1 and 2 – Nighttime



Monthly crashes – Observed and predicted
Severities 1 and 2 – Median crossings



Monthly crashes – Observed and predicted
Severities 1 and 2 – Daytime



APPENDIX C. TABLE OF COMPLETE RESULTS - INTERIM REPORT (18 MONTHS OF BEFORE AND AFTER DATA)

Road Type	Crash Type	Before Period Crash Frequency	Before Period Monthly Mean	After Period Crash Frequency	After Period Monthly Mean	Percent Change	Crash P-Value (one-tail)	Crash Significance (α = 0.05)	Average Speed Significance (α = 0.05)	85th-Percentile Speed Significance (α = 0.05)
	Fatal	29	1.61	40	2.22	37.9%	0.069			
Rural Interstate	Fatal and Major Injury	117	6.50	138	7.67	18.0%	0.070		+	+
	All	2811	156.17	2940	163.33	4.6%	0.363			
	Fatal	19	1.06	21	1.17	10.4%	0.376			
Rural Interstate Daytime	Fatal and Major Injury	70	3.89	75	4.17	7.2%	0.374		+	+
	All	1299	72.17	1325	73.61	2.0%	0.431			
	Fatal	10	0.56	19	1.06	89.3%	0.087			
Rural Interstate Nighttime	Fatal and Major Injury	47	2.61	63	3.50	34.1%	0.143		+	+
	All	1512	84.00	1615	89.72	6.8%	0.373			
	Fatal	15	0.83	16	0.89	6.8%	0.428			
Urban Interstate	Fatal and Major Injury	93	5.17	89	4.94	-4.4%	0.383			-
	All	2685	149.17	2346	130.33	-12.6%	0.106			
	Fatal	51	2.83	42	2.33	-17.7%	0.156			
Rural Express-way	Fatal and Major Injury	183	10.17	178	9.89	-2.8%	0.411		-	-
	All	4365	242.50	4032	224.00	-7.6%	0.277			
	Fatal	105	5.83	140	7.78	33.4%	0.037	+		
Rural Other Primary	Fatal and Major Injury	479	26.61	490	27.22	2.3%	0.412		-	-
	All	8814	489.67	8620	478.89	-2.2%	0.421			
	Fatal	227	12.61	218	12.11	-4.0%	0.365			
Rural Non-Primary	Fatal and Major Injury	1046	58.11	981	54.50	-6.2%	0.162			
	All	15189	843.83	14801	822.28	-2.6%	0.359			
	Fatal	412	22.89	440	24.44	6.8%	0.233			
All Rural	Fatal and Major Injury	1825	101.39	1787	99.28	-2.1%	0.358			
	All	31179	1732.17	30393	1688.50	-2.5%	0.391			