BEFORE AND AFTER STUDY OF SOME IMPACTS OF 4-LANE TO 3-LANE ROADWAY CONVERSIONS

Thomas B. Stout, P.E.
Graduate Student (Ph.D. candidate)
Iowa State University

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Abstract

The safety impacts of the conversion of a 4-lane undivided roadway to a 3-lane roadway are evaluated using classical before and after studies, of some 14 sites using yoked comparison pairs and a comparison to the cities in which the sites are located. Iowa DOT data bases were used to evaluate the changes in the frequency of crashes, rate of crashes, types of injuries, major causes of crashes, and key age groups. The results indicated that the frequency of crashes was reduced by about 24%, when other changes were accounted for, that serious injuries were reduced, that older drivers had a reduced risk of crashing, and that crash types related to left turns and stopped traffic were reduced.

Introduction

Converting the roadway cross-section to a three-lane configuration is frequently suggested as a solution to certain types of crashes on undivided four-lane roadways, particularly in locations where there are physical constraints to solutions that require widening. These crashes usually occur in locations with high left-turning volumes and are either right-angle or rear-end crashes related to left-turns or side-swipe crashes related to lane changes. Because the high volume of left turns essentially converts the inside lanes to de facto left-turn lanes, through traffic is forced to occupy the outside lanes. This limits the capacity of the roadway to that of a two-lane roadway. In those cases where the through volume does not exceed this two-lane capacity, the replacement of the inside through lanes with a continuous two-way left-turn lane can be a viable alternative to full reconstruction. This is particularly the case when there are constraints on widening the roadway, such as a limited right-of-way or limits on funding.

Conceptually such a conversion provides an attractive solution, as it provides a separation between through and left-turning vehicles. Vehicles in the left-turn lane are positioned such that oncoming traffic is (generally) more visible. Drivers need only identify a gap in a single lane of traffic, rather than in two lanes. Because left-turning vehicles are out of the through lane, the risk of rear-end crashes should be reduced. Because through traffic does not need to change lanes there should also be a reduction in the risk of side-swipe crashes.

The Iowa Department of Transportation, as well as several cities, has been extremely interested in these conversions, having recommended and implemented them in high-crash locations at locations across the state. The DOT has been evaluating the impacts of these conversions on the traveling public and this paper provides a preliminary report on this evaluation.

Literature Review

Huang et al evaluated twelve "road diets" in Washington and California (1). The lengths of the sites studied ranged from 0.08 miles to 2.54 miles. They also included twenty-five comparison sites, ranging from 0.13 miles to 3.03 miles. Their analyses included yoked comparisons and fitting negative binomial regression models (applied to the crash frequencies at each site with volume data). They found that the road diets had an average crash frequency that was about 6% lower than the yoked comparison sites. They also found crash severity did not change significantly from the before to the after periods, and it was essentially the same at the diet and comparison sites. They found that there were differences in types of crashes between the road diet and comparison sites; they could not explain the differences. Finally, they found that crash rates did not differ significantly from the before to the after periods.

In 2001 the Center for Transportation Research & Education at Iowa State University published a final report by Knapp and Giesse which presented guidelines for the conversion of 4-lane roadways to a 3-lane configuration. In this report the results of case studies in Montana, Minnesota, California, and Iowa are discussed. In all cases there were reductions in crashes after the conversions, either in terms of numbers or rates of crashes, or both. They also reported that levels-of-service were not "dramatically decreased" by the conversion. There were some operational improvements noted and some sites experienced a reduction in traffic volumes. This may be a result of drivers seeking other routes, a finding also of Huang et al. Knapp and Giesse also reported on the modeling of the operation of the Sioux Center conversion, to evaluate the travel speed and delay. Travel time was found to increase from 50 seconds to 68 seconds, with the average free-flow speed being reduced from about 35 mph to about 32 mph and the number of excessively speeding drivers being reduced by about 70 percent

Purpose of Research

The Iowa DOT, based on anecdotal evidence from various sources concerning a number of conversions, believed that there was a safety benefit to converting 4-lane roads to a 3-lane section and wanted to conduct an independent evaluation of the effectiveness of these conversions that had been made in Iowa. The focus of this research has been to evaluate the safety impacts of the conversion of 14 roadways from a 4-lane undivided configuration to a 3-lane configuration with 1 through lane in each direction and a two-way left-turn lane. Table 1, which follows, lists the cities studied, each city's population (2000 census), the roadway which was converted, and the year of the conversion.

CITY	POPULATION	ROADWAY	YEAR
Blue Grass	1,169	Old US 61	1999
Council Bluffs	58,268	US 6	2000
Des Moines	198,682	Beaver Dr.	1999
Glenwood	5,358	US 275	1998
Indianola	12,998	Iowa 92	1999
Iowa Falls	5,193	Old US 20	2002
Lawton	697	US 20	2000
Manchester	5,257	Iowa 13	2001
Mason City	29,172	Iowa 122	2001
Osceola	4,659	US 34	2001
Rock Rapids	2,573	Iowa 9	1998
Sioux Center	6,002	US 75	1999
Sioux City	85,013	Transit Ave	2000
Storm Lake	10,076	Iowa 7	1993

Table 1 – Study Cities

This study considered a variety of safety-related impacts of the conversions, including the following:

- Change in total number of crashes
- Change in the nature of the crashes
- Change in the injury character of the crashes
- Change in the severity of the crashes
- Change in the major causative factors
- Changes in the involvement of drivers 65 and older, 75 and older, and 25 and younger

Methodology

The approach to the analyses in this study was a classical before and after study of crash data covering periods of up to five years before and after the conversion. In order to compensate for temporal and location related effects, the study also compared crash data for each city overall as well as for similar (yoked comparison) sites that were not converted. The yoked sites were selected using the following criteria:

- Roadway volume (ADT) within 20% of the study roadway
- City population within 20% of the study roadway's city population (a nearby roadway was used in the Des Moines and Storm Lake studies; in all other cases it was necessary to find sites in other cities)
- Similar "character" (this was examined by referring to aerial photography to consider types of development, number of access points, and physical limitations or other topographic features)
- Roadway segment of approximately the same length.

The initial step in the analysis involved the collection of crash data from DOT records. The general procedure was the same for all cases, whether a conversion site or a comparison site. Study segments were identified in the State roads' data base; crashes within 50 meters of these segments were selected using ArcGIS. Figure 1 shows a screen capture of the Blue Grass site on old U.S. 61. The study segment is the east-west roadway at the bottom of the urban area; crashes are the small diamonds on the roadway. The new U.S. 61 bypass is clearly visible to the north of town.

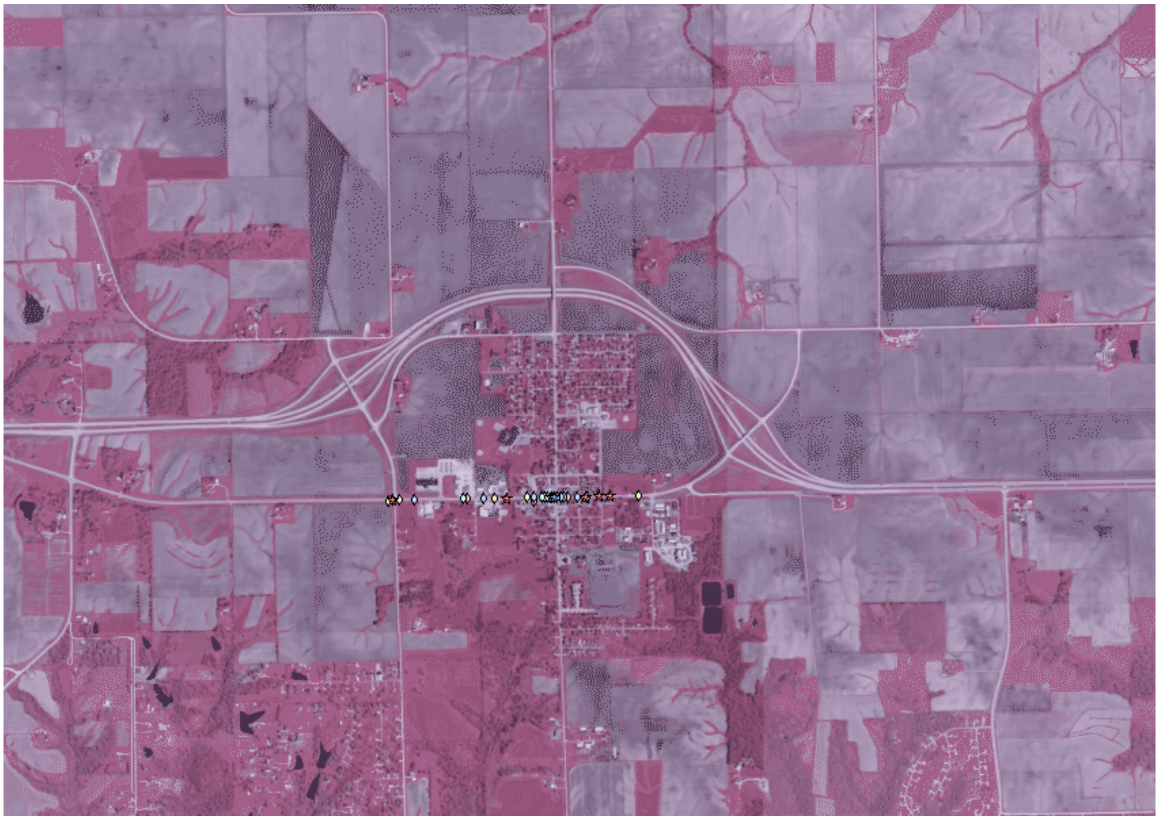

Figure 1 – Old US 61, Blue Grass

For each site the before case was taken as five years preceding the conversion year; the after case was taken as the years following the conversion year, up to five years total. Only the Storm Lake conversion did not include the full five years of before data; it was converted in 1993 but DOT data were not available for years before 1991. Table 2 includes a summary of the before and after data for each of the study sites analyzed.

Within ArcGIS the selected crash files were joined or related to specific data files as appropriate. Files with a one-to-one relationship to each other (such as the location information) can be joined; files with a many-to-one relationship (such as the types of injuries) need to be related. The ArcGIS software allows the capture of various data as database files, in the dbf format. These files were then input to Excel, where they were combined, summarized, and compared using basic arithmetic and graphing functions.

Results

As seen in Table 2, the initial comparison was of the number of crashes before and after conversion and the percentage of reduction that was achieved. These represent an average improvement of 53%. However, there has been a continuing reduction in crashes throughout Iowa and this reduction needs to be factored into any evaluation of the efficacy of a roadway improvement.

CITY	BEFORE	AFTER	%CHANGE
Storm Lake	64	34	-47
Mason City	9	4	-56
Osceola	47	22	-53
Manchester	15	11	-27
Iowa Falls	21	8	-62
Rock Rapids	6	2	-67
Glenwood	30	15	-50
Des Moines	67	39	-42
Council Bluffs	8	2	-75
Blue Grass	12	3	-75
Sioux Center	65	23	-65
Indianola	29	24	-17
Lawton	6	2	-67
Sioux City	5	3	-40

Table 2 – Average Annual Crashes

There are two possible causes for this downward trend. The first is that there has been an ongoing effort to improve the safety of roadways in Iowa (resulting in an overall reduction in crashes and fatalities). The second is that there have been changes in the recording of crashes in Iowa. These changes include an increase in the cost threshold for reporting crashes, from $500 to $1,000, as well as changes in the methodology and format for reporting crashes. The format change occurred in 2001 and has resulted in an anomaly in the data bases. The methodology change has been to remove the requirement for driver self-reporting of crashes, when a police officer responds to the crash. This has resulted in fewer reported crashes. There has been somewhat of an anomaly in the newer crash data, particularly in 2001, and there has been some variation in the reported data depending on when these data were obtained. The overall impact on the results of this is minor, because there were very few added crashes on the study segments. It appears that the primary result would depend on the timing of the anomaly compared to the conversion. If the conversion was in 2000 or prior (9 cases) the effect would be to slightly over-represent the improvement effects due to the conversion. If the conversion was in 2001 (the anomalous year – 3 cases) it should have no effect. For the single case where the conversion occurred after 2001 the effect would be to slightly under-represent the improvement effects.

As mentioned, two additional analyses were undertaken to account for this long-range reduction in crashes. The first was to compare the history of crashes on the study segment with the history of crashes in the cities in which the segments are located. The selection process for these crashes was similar to that for the study segments. Working within ArcGIS, each city's streets were selected from the state road database. Crashes were then selected for the same years as for the study segment being compared. As before, data base files (in dbf format) were created and input to Excel spreadsheets for the basic analyses. Table 3 presents the results of this comparison of the change in crashes between the segments and the cities.

CITY	SEGMENT	CITY	DIFFERENCE
Storm Lake	-47	-21	-26
Mason City	-56	-5	-51
Osceola	-53	-13	-40
Manchester	-27	-17	-10
Iowa Falls	-62	-17	-45
Rock Rapids	-67	-23	-44
Glenwood	-50	-33	-17
Des Moines	-42	-20	-22
Council Bluffs	-75	-34	-41
Blue Grass	-75	-68	-7
Sioux Center	-65	-53	-12
Indianola	-17	-24	7
Lawton	-67	-57	-10
Sioux City	-40	-28	-12
Average	-53	-30	-24

Table 3 – Segment vs. City Crash Change Percentages

Using this method, the average effectiveness of the conversion becomes a 24% reduction in crashes (rounding accounts for the slight difference in the values). The second analysis to account for temporal changes in crashes was the yoked comparison pairs. As was described above, similar but unconverted sites were selected and analyzed for changes in crashes. The selection process for crashes was as described before. Table 4 presents the results of this evaluation.

CITY	SEGMENT	CITY	DIFFERENCE	SEGMENT	YOKED	DIFFERENCE
Storm Lake	-47	-21	-26	-47	-54	7
Mason City	-56	-5	-51	-56	30	-86
Osceola	-53	-13	-40	-53	-11	-42
Manchester	-27	-17	-10	-27	-39	12
Iowa Falls	-62	-17	-45	-62	-38	-24
Rock Rapids	-67	-23	-44	-67	-3	-64
Glenwood	-50	-33	-17	-50	-19	-31
Des Moines	-42	-20	-22	-42	-11	-31
Council Bluffs	-75	-34	-41	-75	19	-94
Blue Grass	-75	-68	-7	-75	-5	-70
Sioux Center	-65	-53	-12	-65	-33	-32
Indianola	-17	-24	7	-17	-18	1
Lawton	-67	-57	-10	-67	-22	-45
Sioux City	-40	-28	-12	-40	-5	-35
Average	-53	-30	-24	-53	-15	-38

Table 4 –Percent Changes in Crashes for Study Segments, Cities, and Yoked Pairs

As may be readily observed, there is a much greater variation in the changes in crashes in the yoked segments. The resulting average change for the yoked segments is smaller, resulting in a greater difference in crash reduction between the study segments and the yoked segments, implying a greater degree of effectiveness for the conversions than was the case for the traditional study. It is likely that much of this difference is an artifact of the selection of the yoked segments; care should be used in using this reduction to predict the benefits from a proposed conversion project and it may be more appropriate to rely on the results from the segment vs. city comparison.

As Table 5 shows, the types of crashes changed noticeably from before to after conversion.

CITY	2	3	4	5	6	7	9
Blue Grass	25.0	-47.9	-100.0	-50.0	-72.2		-91.7
Council Bluffs		-89.6	66.7	66.7	-100.0		-100.0
Des Moines	-58.3	9.8	-84.2	6.4	87.5	150.0	-61.1
Glenwood	-30.8	-28.8	0.0	-34.7	37.5	300.0	-86.7
Indianola	-37.5	19.9	-50.9	1.6	42.9		-77.9
Iowa Falls	-9.1	-72.2	-64.3	-100.0	-100.0	150.0	-100.0
Lawton		-100.0	-100.0	-16.7	-58.3		-100.0
Manchester	150.0	8.7	-75.0	-50.0	87.5	-100.0	-100.0
Mason City	25.0	-85.3		-16.7	-100.0		-100.0
Osceola	-31.8	-35.8	13.6	-74.1	-91.7	25.0	-100.0
Rock Rapids	0.0	-71.4	-100.0	0.0	-90.0		-100.0
Sioux Center	-89.6	0.7	-81.4	-37.5	-54.2	25.0	-95.5
Sioux City	-58.3	66.7		-58.3	66.7		-100.0
Storm Lake	1066.7	128.4	-68.3	-60.0	-69.7		-52.4
Overall	-41.7	-35.0	-73.5	-40.9	-49.3	100.0	-85.2

Table 5 – Percent Change in Type of Crash for Study Segments

Crash type code numbers are as follows:

- 2 – head on
- 3 – rear end
- 4 – angle, on-coming left turn
- 5 – broadside
- 6 – side-swipe same direction
- 7 – side-swipe opposite direction
- 9 -- unknown

The DOT was especially concerned that there be no increase in the number of injury crashes. Figure 2 presents a graphical summary of the results of the analysis of injury crashes. Fatal crashes were reduced by 58%, major injury crashes by 40%, minor injury crashes by 69%, and possible injury crashes by 57%. Overall, injury crashes were reduced by 61%.

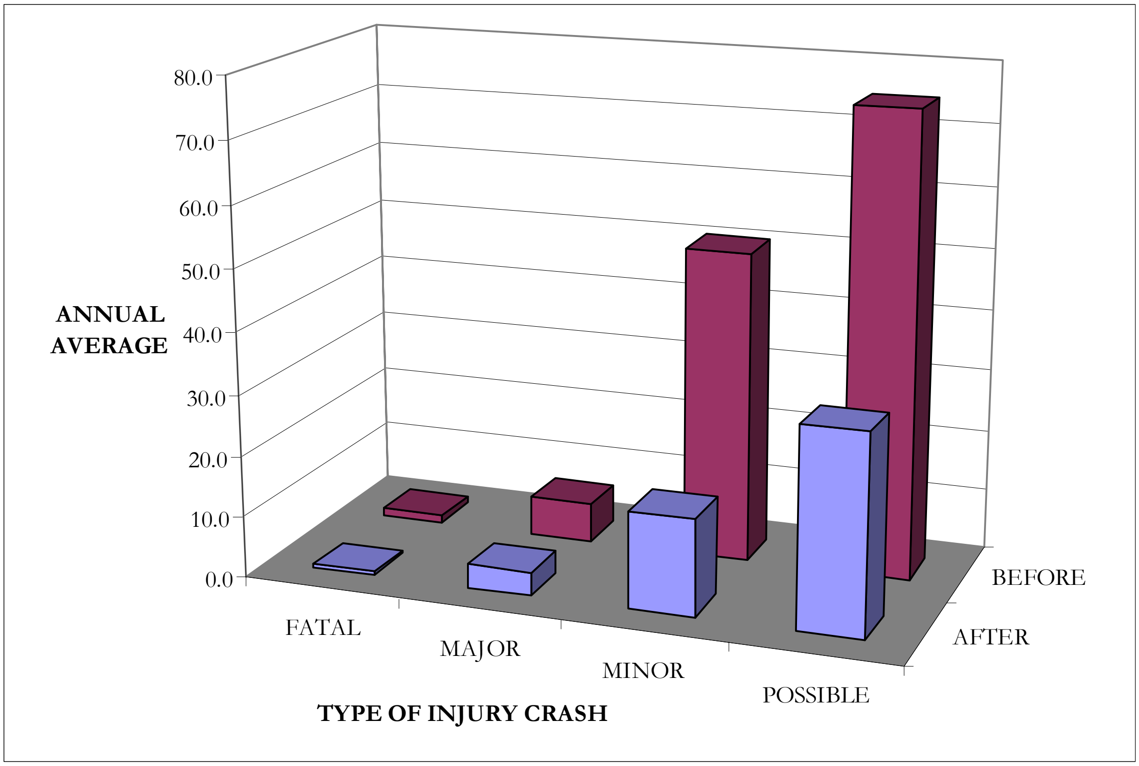

Figure 2 – Before and after comparison of injury crashes

Iowa has a relatively high proportion of elderly drivers; it was a concern of the DOT that older drivers not have a higher rate of involvement in crashes after the conversions. Figure 3 shows the breakdown by age of drivers in crashes in the study segments for the before and after cases.

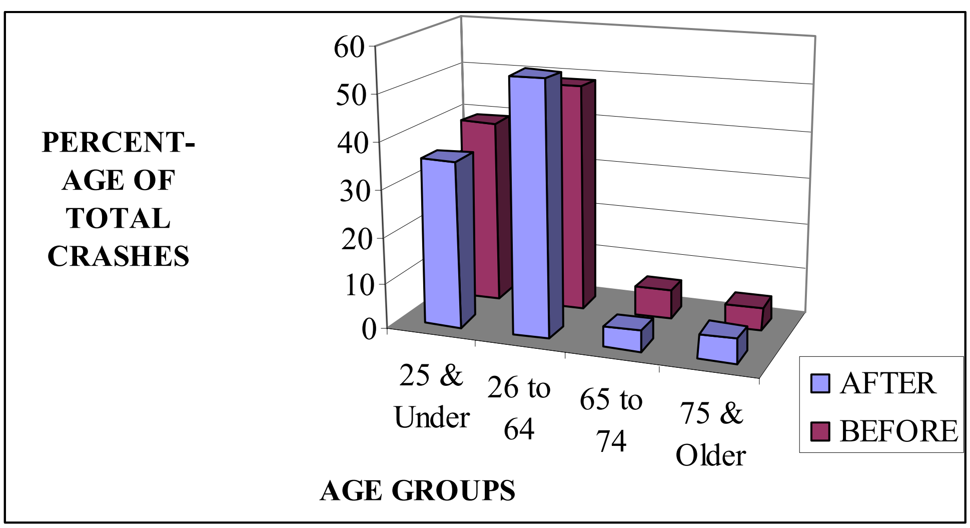

Figure 3 – Driver involvement by Age for all sites, in percent

In both relative and absolute numbers the involvement of drivers 25 and under, as well as drivers 65 to 74, decreased from before to after. There was a slight increase in the proportion of drivers 75 and older, although their absolute numbers decreased slightly.

Conclusions

The conclusions of this evaluation are that there are a number of benefits that can be realized from the conversion of 4-lane undivided roadways to 3-lane cross sections in locations where physical or environmental constraints militate against options that involve widening. These benefits include:

- A reduction of about 24% in the frequency and rate of crashes
- A similar reduction in the number and severity of injury crashes
- Reductions in the involvement of age groups that are traditionally at risk, those 35 and under as well as those 65 and older
- A significant reduction in the number of crashes types related to left-turns and stopped traffic.

Acknowledgements

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References

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Knapp, Keith K., and Karen Giesse, *Guidelines for the Conversion of Urban Four-Lane Undivided Roadways to Three-Lane Two-Way Left-Turn Lane Facilities*, final report, Center for Transportation Research & Education, Iowa State University (2001)