

**MATCHED PAIR SAFETY ANALYSIS OF FOUR-LANE TO
THREE-LANE ROADWAY CONVERSIONS IN IOWA**

Thomas B. Stout, P.E.
Graduate Student/Research Assistant
Iowa State University
Center for Transportation Research & Education
Suite 3100
2901 S. Loop Drive
Ames IA 50010
(515) 294-7188
(515) 294-0467 (fax)
stouttom@iastate.edu

MATCHED PAIR SAFETY ANALYSIS OF FOUR-LANE TO THREE-LANE ROADWAY CONVERSIONS IN IOWA

Thomas B. Stout

ABSTRACT

The safety impacts of the conversion of a number of 4-lane undivided roadways to three lanes are evaluated in a classical before and after study conducted on 11 sites in Iowa. The study included yoked control sites and a comparison to the cities in which the study 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. Five years of before and up to five years of after data were utilized. The analysis also evaluated the relationship of driveway density to crash risk. While previous studies have indicated that 4-lane to 3-lane conversions reduce crash rates by only six percent, the results of the present study indicated that the frequency and rate of crashes was reduced by 21 to 38 percent when adjusted for overall trends in crash performance. Serious injury crashes were reduced, older drivers had a reduced risk of crashing, and left turn and stopped traffic crashes were also significantly reduced. The results of the driveway density analysis indicate a small positive correlation between that density and potential benefits of conversion.

MATCHED PAIR SAFETY ANALYSIS OF FOUR-LANE TO THREE-LANE ROADWAY CONVERSIONS IN IOWA

Thomas B. Stout

INTRODUCTION

Converting roadway cross-sections to a three-lane configuration (a type of road diet) is frequently suggested as a solution to certain types of crashes on undivided four-lane roadways. 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 through 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 (~13-16,000 ADT), 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 to widening the roadway, such as a limited right-of-way or serious funding limitations.

Conceptually, such a conversion is 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. Reducing the number of lanes makes it possible to provide additional width to the remaining lanes or to add bicycle lanes. Crossing vehicles, pedestrians, and bicyclists can also benefit from the reduced number of lanes to cross. However, there are some negative issues that may create problems, such as the possible use of the turn lane as a passing lane and the failure of left-turning vehicles to use the turn lane (making their turn from the through lane). There are several factors that should be considered before implementation of a 4-lane to 3-lane conversion, including the types of crashes, the through traffic volume, and the number of access points within the corridor.

The Iowa Department of Transportation (DOT), as well as several cities, has recommended and/or implemented conversions in high-crash locations at locations across the state. Subsequently, the DOT requested an evaluation of the impacts of these conversions and this paper reports on this evaluation.

LITERATURE REVIEW

In previous research, Huang et al evaluated twelve “road diets” in Washington and California (1). The sites studied ranged in length 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 (matched-pair) comparisons and the fitting of negative binomial regression models (applied to the crash frequencies at each site with volume data). They found that the road diet sites had an average crash frequency about 6 percent 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. While they found differences in types of crashes between the road diet and comparison sites, they did not explain the differences. Finally, they found that crash rates did not differ significantly from the before to the after periods.

Knapp and Giese (2) presented guidelines for the conversion of 4-lane roadways to a 3-lane configuration. In that report, the results of case studies in Montana, Minnesota, California, and Iowa were discussed. In all cases there were reductions in crashes after the conversions, measured by frequency and rate. They also reported that level-of-service was not “dramatically decreased” by conversion. Some operational improvements were noted and a few sites experienced a reduction in traffic volumes. This was thought to perhaps be the result of drivers seeking other routes (also an observation of Huang et al). Knapp and Giese 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, average free-flow speed was reduced from about 35 mph to about 32 mph, and the number of excessively speeding drivers was reduced by about 70 percent

In another study, Hummer and Lewis (3) reported that three-lane cross-sections have lower collision rates than four-lane cross-sections across all “development categories.” They also observed that collision rates increase much more rapidly (compared to three-lane cross-sections) for two-lane and four-lane undivided cross-sections as the density of development increases. That also determined that “(a)bove about 12,000 vehicles per day, two-lane and three-lane cross-sections will operate at level of service E or F during the peak period of the day.”

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 undivided 4-lane roads to a 3-lane section and desired an independent evaluation of the effectiveness of these conversions that had been made in Iowa. Therefore the focus of this research was to evaluate the safety impacts of the conversion of 11 roadways from a 4-lane undivided configuration to a 3-lane configuration with one through lane in each direction and a continuous two-way left-turn lane, using classical statistical techniques. Table 1 lists the cities studied, together with each city’s population (2000 census), the roadway which was converted, and the year of the conversion.

TABLE 1 Study Cities

CITY	POPULATION	ROADWAY	YEAR
Blue Grass	1,169	Old US 61	1999
Des Moines	198,682	Beaver Dr.	1999
Glenwood	5,358	US 275	1998
Indianola	12,998	Iowa 92	1999
Iowa Falls	5,193	US 65	2002
Manchester	5,257	Iowa 13	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

This study presents a before-after evaluation using yoked (matched) pairs of comparison sites for a variety of safety-related impacts of the conversions, including changes in:

- frequency of crashes
- crash rate
- nature/type of crashes
- injury character or severity of the crashes
- involvement of drivers 65 and older, 75 and older, and 25 and younger

Another objective of the reported study was to examine and quantify, to the extent possible, the “character” of the conversion sites, to investigate its relationship to the safety-related impacts. The principal metric of character is driveway density, as turn-related crashes are a major part of the usual justification for a four-lane to 3-lane conversion. Driveway density also serves as a proxy for level and type of development in the area.

METHODOLOGY

A classical before and after study was conducted using crash data covering periods of five years before and up to five years of data after the conversion. In order to compensate for the effect of overall trends in crash performance, the study compared site to citywide crash statistics for both converted and yoked control sites. Control sites were selected using the following criteria:

- 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” (aerial photography was used to assess type of development, number of access points, and physical limitations/topographic features)
- Length within 20% of the study roadway.

Study segments were identified from the DOT road data base and crashes within 50 meters of these segments were selected using ArcGIS. As an example, Figure 1 shows 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 north of town.



FIGURE 1 Old US 61, Blue Grass (Iowa)

For most sites, before data were obtained for the five years preceding the conversion year. Only the Storm Lake conversion did not include the full five years of before data as it was converted in 1993 (the DOT crash data base used went back to 1991). As 2003 was the most recent full year of crash data available at the time of this study, after data ranged from one to five years.

Using ArcGIS, the selected crash files were joined or related to specific data files as appropriate. The GIS data were exported to Excel where they were analyzed and presented.

Driveway counts were determined using 2002 USGS 1-meter color-infrared aerial photography, as illustrated in Figure 1. Driveway density was computed by dividing the number of driveways in a section by the length of the section in miles.

RESULTS

Crash Frequency

As seen in Table 2, an initial comparison indicates an average crash reduction of 50%. However, these improvements are not exclusively the result of the 4 to 3

conversion. There are two probable causes for this downward trend. The first relates to ongoing efforts to improve the safety of roadways in Iowa (resulting in an overall reduction in crashes and fatalities) and of automobiles in general. The second relates to an increased reporting threshold in Iowa (\$500 to \$1,000), as well as changes in the Iowa Crash Reporting Form occurring in 2001. Also, after 2001, drivers are no longer required to self-report when a police officer responds to the crash, resulting in fewer reported crashes. The overall impact on the results of these changes is minor, and depends on the timing of the conversion. For conversions prior to 2001 (7 cases) the effect is to slightly over-represent crash reductions. For conversions in 2001 (2 cases) there is no effect. For the single case where the conversion occurred after 2001 the effect is to slightly under-represent the improvement effects. The Storm Lake conversion “after” period concluded prior to 2001.

TABLE 2 Average Annual Crashes

CITY	BEFORE	AFTER	%CHANGE
Storm Lake	64	34	-47
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
Blue Grass	12	3	-75
Sioux Center	65	23	-65
Indianola	29	24	-17
Sioux City	5	3	-40
Average	28	14	-53

To adjust the reported crash reductions for these overall trends, crash history on the study segment were compared to crash history for the cities in which the segments are located. Table 3 presents the results of this comparison of the change in crashes between the segments and the cities. This adjustment results in an average of a 21 percent reduction in crashes.

TABLE 3 Segment vs. City Crash Count Changes (%)

CITY	SEGMENT	CITY	DIFFERENCE
Storm Lake	-47	-21	-26
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
Blue Grass ¹	-75	-68	-7
Sioux Center	-65	-53	-12
Indianola	-17	-24	7
Sioux City	-40	-28	-12
Average	-50	-29	-21

A second method to adjust for overall changes was a yoked comparison analysis. Similar but unconverted sites were selected and analyzed for changes in crashes. Table 4 presents the results after this adjustment.

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

CITY	SEGMENT	CITY	DIFFERENCE	SEGMENT	YOKED	DIFFERENCE
Storm Lake	-47	-21	-26	-47	-55	8
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
Blue Grass	-75	-68	-7	-75	-5	-70
Sioux Center	-65	-53	-12	-65	-33	-32
Indianola	-17	-24	7	-17	-18	1
Sioux City	-40	-28	-12	-40	-5	-35
Average	-50	-29	-21	-53	-15	-38

The resulting average change for the yoked segments is smaller than that computed for the study cities, resulting in a greater difference in crash reduction between the study segments and the yoked segments. This results in a greater average adjusted reduction, 38 percent.

¹ A bypass was built around Blue Grass in the after period, thus removing a large proportion of the total traffic and likely reducing the number of crashes for both the segment and the city.

Crash Rates

An analysis of crash rates shows results that are similar to the changes in the crash counts, as shown in Table 5. Again, the segments show a 50 percent unadjusted decline in crash rate and a 23 percent decline when adjusted using the yoked pair performance.

TABLE 5 Percent Changes in Crash Rates

CITY	STUDY SEGMENT			YOKED SEGMENT			NET %
	BEFORE	AFTER	% CHANGE	BEFORE	AFTER	% CHANGE	CHANGE
Storm Lake	13.40	8.18	-39	16.46	7.31	-56	17
Osceola	8.88	3.40	-62	3.63	3.49	-4	-58
Manchester	12.26	7.60	-38	8.34	3.10	-63	25
Iowa Falls	4.82	1.75	-64	3.15	2.00	-37	-27
Rock Rapids	10.23	3.31	-68	4.77	3.67	-23	-45
Glenwood	12.60	6.28	-50	7.36	4.85	-34	-16
Des Moines	11.13	6.57	-41	6.14	5.48	-11	-30
Blue Grass	6.23	2.86	-54	7.42	7.62	3	-57
Sioux Center	11.13	4.45	-60	9.02	6.37	-29	-31
Indianola	4.85	3.18	-34	11.90	10.29	-14	-20
Sioux City	1.94	1.34	-31	4.26	4.99	17	-48
Average	8.861	4.446	-50	7.889	5.208	-27	-23

Crash Type and Severity

As Table 6 shows, the types of crashes changed noticeably after conversion. While almost all categories of crash experienced very significant decrease, interestingly, the average sideswipe-opposing fraction increased significantly in the after period. No explanation is offered for this observation.

The DOT was especially concerned about injury crashes. For the conversion sites, fatal crashes were reduced by 58%, major injury crashes by 40%, minor injury crashes by 67%, and possible injury crashes by 56% (see figure 2). Overall, injury crashes were reduced by 59%. Adjusted for citywide trends, the reductions are 35% for fatal crashes, 11% for major injury crashes, 34% for minor injury crashes, and 29% for possible injury crashes. The overall adjusted reduction of injury crashes (all types) is 27%.

TABLE 6 Percent Changes in Type of Crash for Study Segments

CITY	Head-On	Rear-End	Angle/Left-turn	Broadside	Sideswipe-same	Sideswipe - opposing	Unknown
Blue Grass	25.0	-47.9	-100.0	-50.0	-72.2		-91.7
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
Manchester	150.0	8.7	-75.0	-50.0	87.5	-100.0	-100.0
Osceola	-54.5	-48.5	0.0	-82.8	-91.7	25.0	-87.2
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
Average	-44.7	-29.3	-74.3	-40.8	-44.9	77.8	-83.1

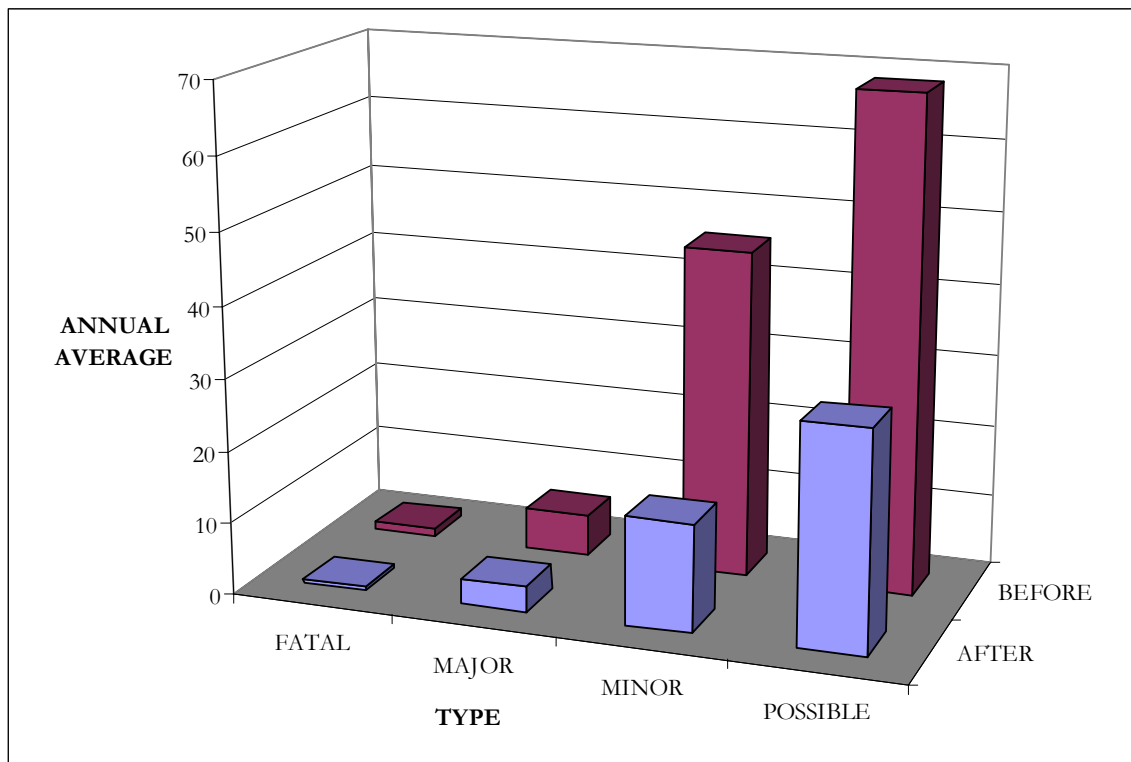


FIGURE 2 Before and After Comparison of Injury Crashes

As Iowa has a high proportion of elderly drivers; the ability of four-lane to three-lane conversions to address older driver crash issues was of interest. Figure 3 shows an analysis by age of driver for the before and after cases. In both relative and absolute numbers the involvement of drivers 25 and under, as well as drivers 65 and older, decreased after conversion.



FIGURE 3 Driver Involvement by Age for All Sites, in Percent

Effect of Driveway Density

An analysis of driveway density and crash risk found a stronger pre-conversion correlation (see Figure 4) The relationship between the driveway density and the change in crash rate is shown in Figure 5 indicating that the benefits of 4-lane to 3-lane conversion increases with increasing driveway density.

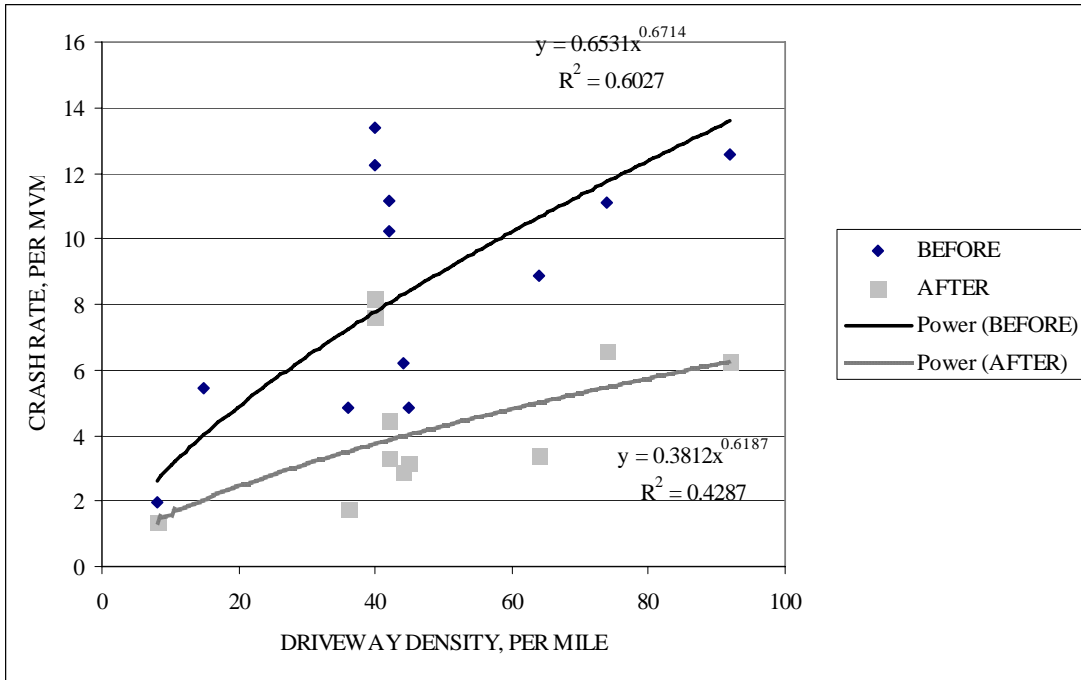


FIGURE 4 Driveway Density vs. Crash Rate

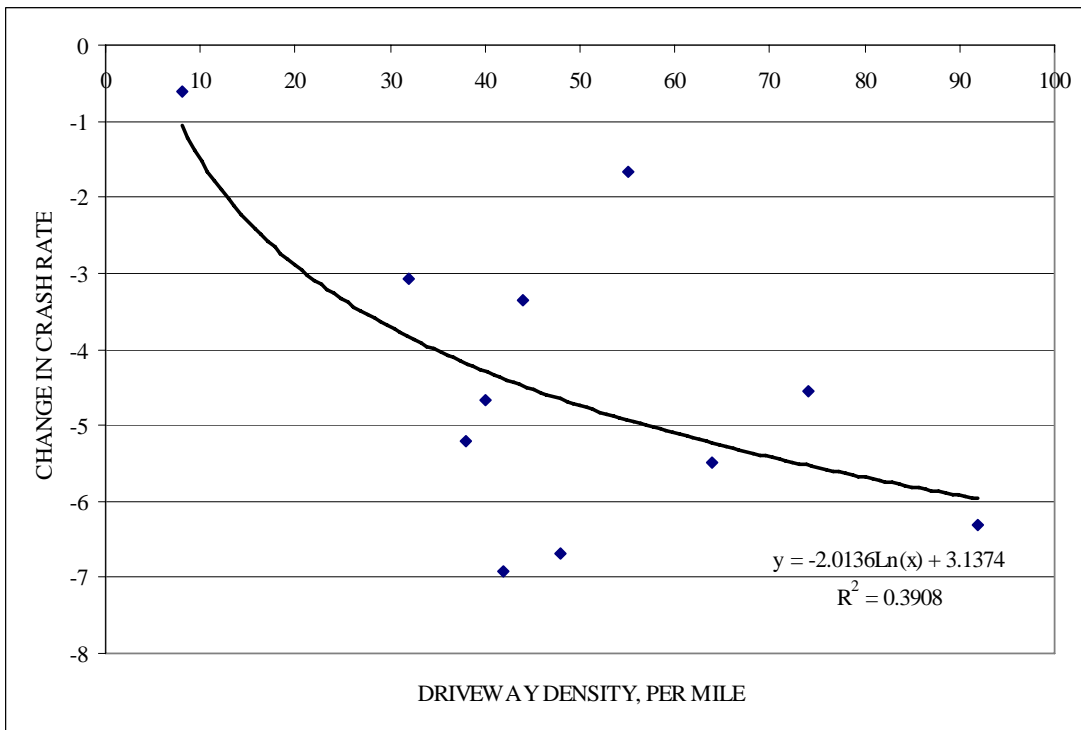


FIGURE 5 Driveway Density vs. Change in Crash Rate

CONCLUSIONS

This study indicates that a number of benefits can be realized from the conversion of 4-lane undivided roadways to 3-lane cross sections in selected locations where physical or other constraints restrict options that involve widening. In general, success is more likely where:

- There is a history of crashes that are amenable to solution by providing a two-way left-turn lane
- Traffic volume is generally less than about 20,000 ADT
- There is a high density of access points²
- There are large turning volumes

The benefits of conversion may include the following:

- A reduction of 21 to 38 percent 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 25 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.

Finally, there appears to be a slight positive correlation between driveway density and the expected benefits of the four-lane to three-lane conversion. For example, a segment with a driveway density of 20 per mile would be expected to experience about a 50 percent reduction in the average crash rate, whereas a segment with density of 90 might be expected to have a reduction of around 54 percent. However, the models do not have high correlation coefficients.

LIMITATIONS

One of the limitations of the classical before-after study is that it does not address the regression-to-the-mean phenomenon (see for example Hauer (4)). To some degree the richness of the data base utilized (up to 5 years before and after) will compensate for this phenomenon. The Iowa DOT recognized this as a potential limitation of the classical method and has completed a separate full Bayesian analysis of the crash rates at these sites (conversion and comparison); the results are comparable to the results of this study. Empirical Bayes may also be used to analyze the effectiveness of conversions, provided there is a sufficiently large dataset for computation of required parameters.

One of the limitations in this study of the use of the driveway density as a metric for the site character is that it is difficult to determine, from the aerial photography, the exact count of driveways or the type of driveway. It is frequently the case, particularly in transitional areas, for single family houses to be converted to business or commercial uses. This will clearly increase the amount of vehicle traffic over that expected from the typical home. Using video logs (video records taken along each roadway) to verify both

• ² Locations with few access points may benefit from a “road diet” involving two through lanes and discontinuous left-turn lanes.

the count and types of driveways would make it possible to differentiate between business and residential drives and thus perhaps to better characterize the crash risk.

ACKNOWLEDGEMENTS

I would like to acknowledge the support of the Iowa DOT Office of Traffic and Safety, as well as the Midwest Transportation Consortium, in the conduct of this study.

REFERENCES

1. Huang, Herman F., J. Richard Stewart, and Charles V. Zegeer, "Evaluation of Lane Reduction 'Road Diet' Measures on Crashes and Injuries", Paper No. 02-2955 in Transportation Research Record 1784.
2. Knapp, Keith K., and Karen Giese, *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)
3. Hummer, Joseph E. and Conrege F. Lewis, "Operational Capacity of Three-Lane Cross-Sections, Final Report for Research Project 23241-97-1", Center for Transportation Engineering Studies, North Carolina State University (2000)
4. Hauer, Ezra, *Observational Before-After Studies in Road Safety*, Pergamon, Oxford, U.K. 1997