Center for Transportation Research and Education

IOWA STATE UNIVERSITY

RESEARCH PROJECT TITLE
Rural Expressway Intersection Synthesis of Practice and Crash Analysis

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Rural Expressway Intersection Safety

tech transfer summary

Overview

An expressway is a multi-lane, median-divided highway where most intersections are at grade. The typical intersection on a rural expressway is a two-way, stop-controlled (TWSC) intersection where a two-lane roadway (the minor roadway) meets a four-lane expressway (the major roadway or the mainline).

In general, the severity of crashes at most TWSC rural expressway intersections has more to do with traffic volume on the minor road than with traffic volume on the mainline. As traffic volume on the minor road increases, both crash rates and crash severity increase. TWSC intersections on rural commuter routes that are likely to be most problematic are those with moderate volumes on the mainline (10,000 to 12,000 vehicles per day) and high volumes on the minor road (2,000+ vehicles per day), those where minor roadway volumes are highly peaked (e.g., a rural commuter route to an urban job center), and those at or near vertical or horizontal curves on the mainline.

In addition to conventional safety improvements, several innovative safety improvements are available for problematic at-grade expressway intersections.

Problem Statement

Converting two-lane highways to expressways has become a popular improvement in Iowa and many other states. Expressways are now the fastest growing component in the nation's highway system. With fewer interchanges than interstate highways, expressways are less expensive to construct, yet they support similar traffic speeds and capacities and, where there are fewer than five access points per mile, have similar safety records. Still, relatively little is known about the specific safety performance of expressways.

Objectives

The goal of this project was to provide an analysis of crash characteristics for rural expressway, TWSC intersections, and a synthesis of safety strategies at these intersections. Researchers focused on determining the relative impact on crash rates of traffic volumes on both the major and minor roadways, and of intersection geometry (median width, presence of turning lanes, etc.). In addition, researchers conducted a national survey of strategies currently being applied by state transportation agencies to improve safety at TWSC expressway intersections.

Crash Data Methodology/Findings

The project team examined five years of crash data (1996–2000) for 644 Iowa TWSC expressway intersections. Many of the intersections were very low volume, and at 155 of them the minor roads were unpaved (aggregate surface).

First, researchers examined intersection crash rates, crash fatality rates, and crash severity rates relative to traffic volumes on minor roadways.

- Crash rate is the total number of crashes divided by millions of entering vehicles (MEV).
- Fatal crash rate is the total number of fatal crashes divided by hundred million entering vehicles (HMEV).
- The crash severity index assigns a weight of 5 to fatal crashes, 4 to major injury crashes, 3 to minor injury crashes, 2 to possible injury/unknown crashes, and 1 to property-damage-only (PDO) crashes.

Figure 1 shows crash and crash fatality rates plus crash severity index rates averaged over five years, stratified by increasing traffic volumes on the minor roadways. All three rates increase with minor roadway traffic volumes. This

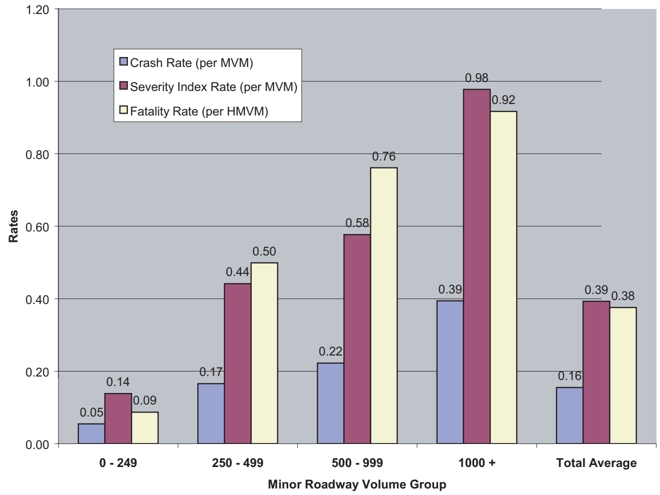

Figure 1. Crash, Severity Index, and Fatality Rates of Rural Expressways by Minor Roadway Volume

indicates that crashes are occurring more frequently and becoming more severe as traffic increases on the minor roads.

Second, researchers examined crash types (head-on, right-angle, rear-end, etc.) relative to both major and minor roadway traffic volumes. (Right-angle crashes tend to be the most severe. They happen when drivers on the minor roadway fail to select an adequate gap between vehicles when crossing the expressway.)

Figure 2 illustrates that as minor roadway traffic volume increases, the percentage of right-angle crashes increases. (Figure 3 illustrates that traffic volume on the expressway itself does not seem to have an impact on crash type.)

To examine this trend another way, researchers looked at 20 TWSC expressway intersections: 10 with the best safety performance and 10 with the poorest safety performance. (Relative safety performance was determined by comparing each intersection's expected crash-severity rate, based on a statistical model, with the actual, observed crash-severity rate. The "best" intersections were those whose actual crash-severity rates were lower than expected; in other words, they performed better than predicted. The "poorest" intersections were those whose actual performance was worse than predicted.)

Table 1 shows average traffic volumes for minor and major roadways at the 10 highest-severity intersections and the 10 lowest-severity intersections.

Table 1. Average Daily Traffic (ADT) on Approaches of High- and Low-Severity TWSC Expressway Intersections

	Average Traffic Volume (ADT) on Major Roadway (Expressway)	Average Traffic Volume (ADT) on Minor Roadway
Low crash-severity intersections	20,360	424
High crash-severity intersections	11,490	2,300
Average for all intersections that experienced at least 1 crash	10,840	1,362

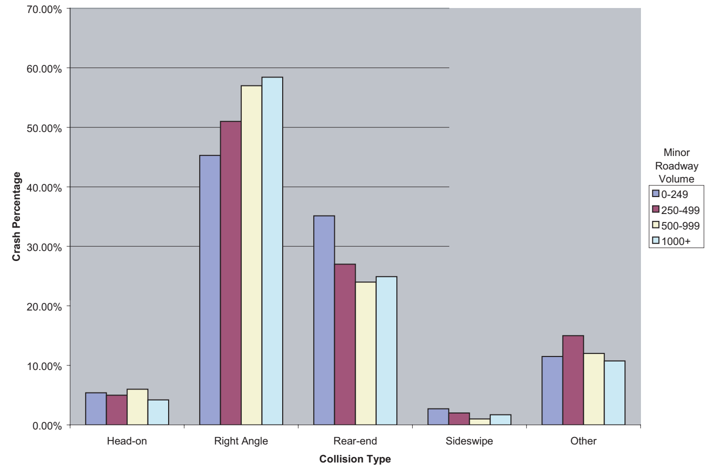

Figure 2. Crash Type by Minor Roadway Volume (without PDO Crashes)

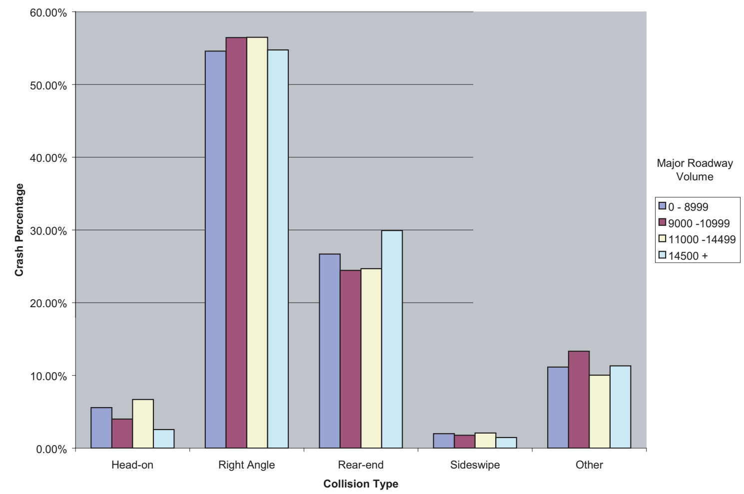

Figure 3. Crash Type by Major Roadway Volume (without PDO Crashes)

As expected, at intersections with low crash-severity ratings, average traffic volumes on the minor roadways were low—well below the overall average. And at intersections with high crash-severity ratings, average traffic volumes on the minor roadways were well above the overall average. Surprisingly, however, the low crash-severity intersections were on the highest volume rural expressways in Iowa.

Figure 4 illustrates the difference in crash type distribution between high crash-severity and low crash-severity intersections. The high crash-severity intersections have a very high involvement of right-angle crashes (66 percent), while the low crash-severity intersections have a low involvement of right-angle crashes.

Other potentially problematic intersections include those

- where minor-roadway drivers' ability to judge gaps in traffic is hindered by horizontal or vertical curves on the expressway.
- with commercial development (gas stations, convenience stores, fast food, etc.), where additional turning movements and higher volumes create more opportunity for crashes.

Survey Methodology/Findings

Electronic surveys were sent to state traffic engineers; 28 states responded. Questions focused on the following:

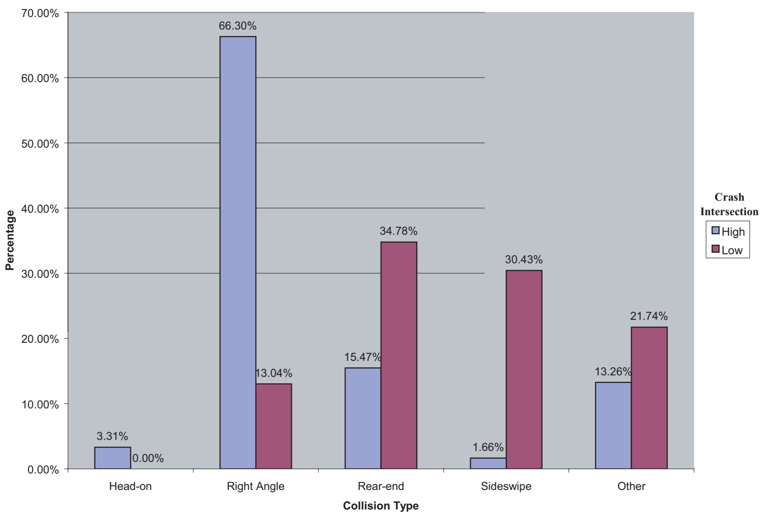

Figure 4. Crash Type Distributions for High and Low Crash-Severity Intersections

- states' experience with expressways (lane miles, criteria for upgrading to an interchange, etc.),
- safety performance of expressways,
- innovative layout/geometry of at-grade intersections on expressways, and
- general respondent comments.

Survey responses indicated that safety at rural TWSC expressway intersections is a growing concern for state transportation agencies that responded to the survey. To remedy this growing concern, many states are applying special treatments to these intersections to improve safety. Several states had subjective evidence of the effectiveness of these countermeasures, but very few states had objective evidence.

The report describes 17 conventional and innovative improvements for expressway intersections being implemented across the country. A few of these improvements are summarized and illustrated below.

Conventional safety improvements

Conventional strategies for these intersections include improving signing on the minor roads and in the median, adding a double-yellow center line in the median and stop/yield bars, adding advance in-lane rumble strips for minor roadway traffic in advance of the stop, and then, depending on the crash type experience, adding left and right turn lanes on the mainline.

If an intersection continues to have crash problems, the next step may be to add traffic signals. A statistical analysis has not been done to determine if signalization improves safety at rural high-speed expressway intersections. It appears, however, that signalization can convert a right-angle crash problem into a rear-end and red-light-running crash problem.

If right-of-way is available, converting an at-grade intersection to an interchange is the ultimate conventional solution, but a costly one.

Innovative safety improvements

Two-movement cues. The problem with crossing a median-divided expressway intersection in one movement is that it is easy to misjudge a gap in the far-lane traffic. Several low-cost strategies focus on providing cues and guidance to encourage drivers on the minor roads to move through the intersection in two movements.

The first movement involves crossing the near lanes and stopping or slowing in the median crossover. The second movement is turning left or crossing the second set of lanes.

Wide medians. Several studies have shown that as median width increases, crash frequency declines. Wider medians encourage drivers to treat the divided expressway lanes as two separate intersections; that is, they encourage a two-movement crossing or left turn. Wide medians also provide ample refuge for long vehicles (e.g., combination trucks and school buses).

However, very wide medians can result in more crashes in the median crossover lanes.

Left-turn acceleration lanes. Unfortunately, not all expressway medians are wide enough to store large vehicles. If widening the median is not feasible, an effective and innovative alternative is adding a left-turn acceleration lane in the median, as shown in Figure 5.

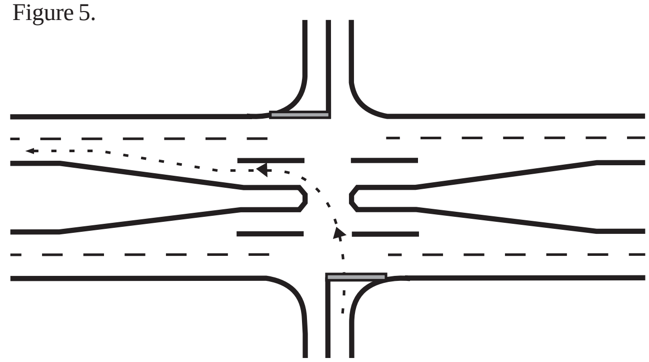

Figure 5. Median left-turn acceleration lane (graphic from Harwood, D.W., "Innovative Intersection Improvements," Midwest Research Institute, Kansas City, MO)

Where this strategy has been applied in Minnesota and Missouri, it has been very popular with drivers and has reduced delays and conflicts.

A left turn using an acceleration/merge lane is much safer and forgiving than a direct left turn into a high-speed travel lane. The acceleration lane provides large, left-turning vehicles a refuge along the median. By the time the vehicle merges into traffic, it is moving at a speed that reduces the likelihood and severity of rear end crashes.

The acceleration lane also reduces the conflict between a left-turning vehicle from the minor road stopped in the median and another vehicle turning left from the expressway. This conflict can be particularly problematic when both vehicles are large trucks.

Ideally, an acceleration lane should be 1,500 feet long to provide heavy trucks with enough distance to accelerate and merge with expressway traffic. Because most drivers are unfamiliar with left-turn acceleration lanes, some driver education is required. Enhanced pavement markings are also needed to encourage proper use of the acceleration lane.

Indirect left turns. Left turns are a factor in a large percentage of intersection crashes. Some states are implementing strategies to replace left turns, and sometimes cross-traffic movements, with indirect movements. To eliminate left turns from the expressway onto a minor road, jughandles, shown in Figure 6, and loops are sometimes used.

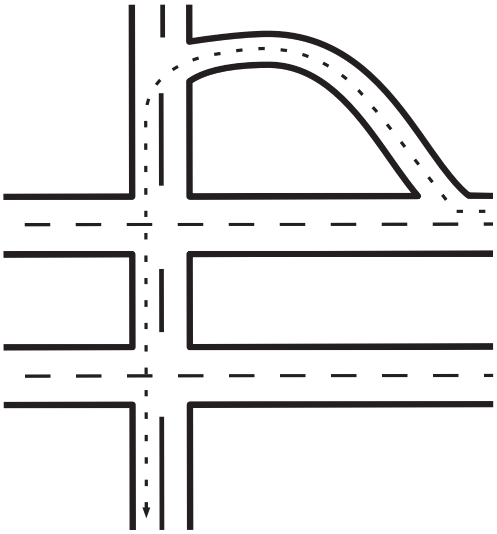

Figure 6. Jughandle (graphic from Harwood, D.W., "Innovative Intersection Improvements," Midwest Research Institute, Kansas City, MO)

To eliminate left turns from the minor road, the median crossover is commonly closed. In Figure 7, left turns are allowed from the expressway, but left turns from the minor road are blocked by a raised median. Drivers wanting to turn left from the minor road are forced to turn right and make a U-turn through the median.

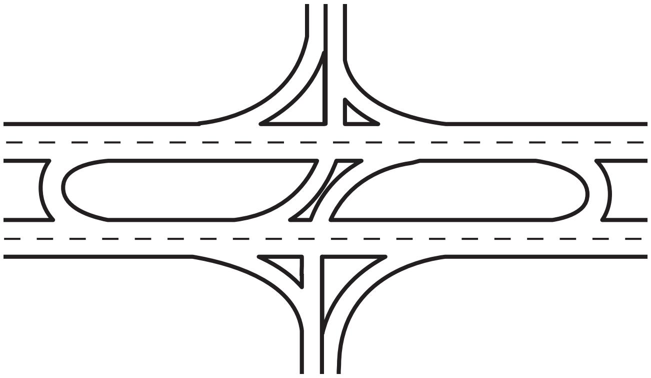

Figure 7. Directional median opening

Grade-separated intersections. A couple of intersection designs have been built in Iowa that include a grade separation and offset "T" intersection. This design concept could serve as a possible interim improvement to a future full interchange. These designs involve constructing a bridge over the expressway (the major cost element of an interchange) but not all the ramps, acceleration lanes, and tapers. Grade-separated intersections are viable alternatives at selected expressway intersections, such as those with narrow medians or restricted rights-of-way or where a lower cost improvement than a full interchange is desired.

An aerial photo of one of Iowa's grade-separated intersections is shown in Figure 8. This design requires all turns to be made on one connecting turning road and through two T-intersections. This design reduces the number of conflict points, and its safety

Figure 8. Intersection of US 59 and US 34 in Mills County, IA

performance is much better than that of similar at-grade intersections. (Turns could be further segregated by building a second connecting turning road in one of the north quadrants of the intersection.) This design also facilitates converting the intersection into a diamond or a partial cloverleaf interchange in the future, if warranted.

Implementation Benefits

Currently, innovative improvements of at-grade, TWSC expressway intersections, like those discussed in this publication, are not widely implemented. It is difficult, therefore, to make general predictions regarding the potential safety benefits of implementing such treatments more widely.

However, actual crash-severity rates at grade-separated intersections are about two-thirds lower than expected crash-severity rates at at-grade TWSC intersections. Conservatively, therefore, it is not unreasonable to estimate that implementing innovative treatments at the 10 worst performing at-grade TWSC intersections could reduce the crash-severity rate by half. Using Iowa DOT economic loss estimates for fatal, severe-injury, minor-injury, and property-damage-only crashes, the economic loss at all 10 intersections is currently about $1,633,500 per year (the average for a total of five years of crash experience). If the distribution of crash severity stays the same, reducing the crash-severity rate by half would save a little over $800,000 per year in crash losses ($80,000 per intersection per year).

A conservative (high) cost estimate to equip an intersection with a directional median and a median U-turn cross-over (similar to Figure 7) is about $250,000; such an improvement would have a 15-year life. Using a 4 percent social discount rate, the annual cost of this treatment is about $21,000, resulting in an operative benefit-cost ratio of approximately 4 to 1.

Implementation Readiness

In general, adequate information exists to identify locations where innovative expressway intersection improvements, like those described herein, may be beneficial. The final report for this project provides additional details about implementing such improvements, as well as information about states that have used these strategies.