# Safety Effects of Offset Right-Turn Lanes at Rural Expressway Intersections

Joshua L. Hochstein
Center for Transportation Research and Education
Iowa State University
2711 South Loop Drive, Suite 4700
Ames, IA 50010-8664
jlhoax@iastate.edu

Thomas H. Maze
Center for Transportation Research and Education
Iowa State University
2711 South Loop Drive, Suite 4700
Ames, IA 50010-8664
tmaze@iastate.edu

Howard Preston
CH2M Hill, Inc.
1295 Northland Drive Suite 200
Mendota Heights, MN 55120
hpreston@ch2m.com

Richard Storm
CH2M Hill, Inc.
1295 Northland Drive Suite 200
Mendota Heights, MN 55120
rstorm@ch2m.com

Thomas M. Welch
Office of Traffic and Safety
Iowa Department of Transportation
800 Lincoln Way
Ames, IA 50010
tom.welch@dot.iowa.gov

**ABSTRACT**

A rural expressway is a high-speed, multilane, divided highway with partial access control. It is typically divided by a wide, depressed median and consists of both at-grade intersections and grade-separated interchanges. Converting undivided rural two-lane highways into expressways is a popular highway safety improvement, as expressways make passing easier and drastically reduce the likelihood of head-on and opposite-direction sideswipe collisions. However, at-grade intersection collisions on rural expressways are reducing the safety benefits that should be achieved when converting rural two-lane highways into expressways. The underlying problem seems to be that expressway intersections present challenges to minor road drivers attempting to select gaps in the expressway traffic stream. State transportation agencies have experimented with several intersection safety treatments at problematic two-way stop controlled (TWSC) rural expressway intersections to improve their safety performance while avoiding costly grade separation. One of these treatments is the offset right-turn lane. The assumed safety benefit of offset right-turn lanes is that they eliminate the sight distance obstruction created by the presence of right-turning vehicles leaving the expressway, thereby allowing minor road drivers to make better gap selection decisions when entering expressway intersections. However, no studies have been conducted to determine the crash reduction potential of this countermeasure. Therefore, this research examines offset right-turn lane implementation at three TWSC rural expressway intersections and documents their safety performance using naïve before-after crash data analysis. The results show that offset right-turn lanes can be effective in reducing the frequency of near-side right-angle collisions occurring at TWSC rural expressway intersections.

**Key words: expressway intersection safety—median intersection design—offset right-turn lanes**

---

*Proceedings of the 2007 Mid-Continent Transportation Research Symposium*, Ames, Iowa, August 2007. 

## INTRODUCTION

A rural expressway is a high-speed ( 50 mph), multilane, divided highway with partial access control. It is typically divided by a wide, depressed turf median and may have intersections that are at-grade or grade-separated. Converting undivided rural two-lane highways into expressways is a popular highway safety improvement used by many state transportation agencies (STAs) because, by providing an extra lane of travel in each direction and a physical separation between opposing traffic flows, expressways make passing easier and drastically reduce the likelihood of dangerous head-on and opposite-direction sideswipe collisions (AASHTO 2004). In addition, these facilities improve the connectivity between cities while promoting economic growth. Overall, the assumption is that expressways are able to provide most of the mobility, capacity, and safety benefits of an interstate, while being constructed at a lower cost (Maze, Hawkins, and Burchett 2004). The popularity of expressway conversion is evidenced by the fact that rural expressway mileage in the U.S. increased by more than 2,600 miles between 1996 and 2002. This expansion is expected to continue, as 26 out of 28 STAs recently surveyed indicated that they plan to expand their state expressway systems over the next ten years (Maze, Hawkins, and Burchett 2004).

The typical rural expressway at-grade intersection, as shown in Figure 1, is a two-way stop controlled (TWSC) intersection, with the stop control on the minor, usually two-lane, roadway. A number of studies have shown that right-angle collisions account for the majority of crashes at these intersections (Maze, Hawkins, and Burchett 2004; Harwood et al. 1995; NDOR 2000; Preston et al. 2004). In addition, an unpublished study conducted by the Nebraska Department of Roads (NDOR) Highway Safety Division (NDOR 2000) revealed that right-angle intersection collisions on their rural expressway system are nullifying the safety benefits that should be derived from converting a number of their rural two-lane highways into expressways. In an effort to develop a better understanding of the causes of these right-angle collisions, Preston et al. (2004) reviewed three years (2000–2002) of crash data at three high–crash frequency TWSC rural expressway intersections in Minnesota and discovered that 87% of the right-angle collisions at these intersections were due to the inability of minor road drivers to recognize oncoming expressway traffic and/or select safe gaps in the expressway traffic stream (i.e., minor road drivers did not see or misjudged the time-to-arrival of an approaching expressway vehicle). Other intersection design features (horizontal/vertical curvature on the expressway, intersection skew, median width, presence of right-turn lanes on the expressway, etc.) may make the task of gap selection more difficult for the minor road driver.

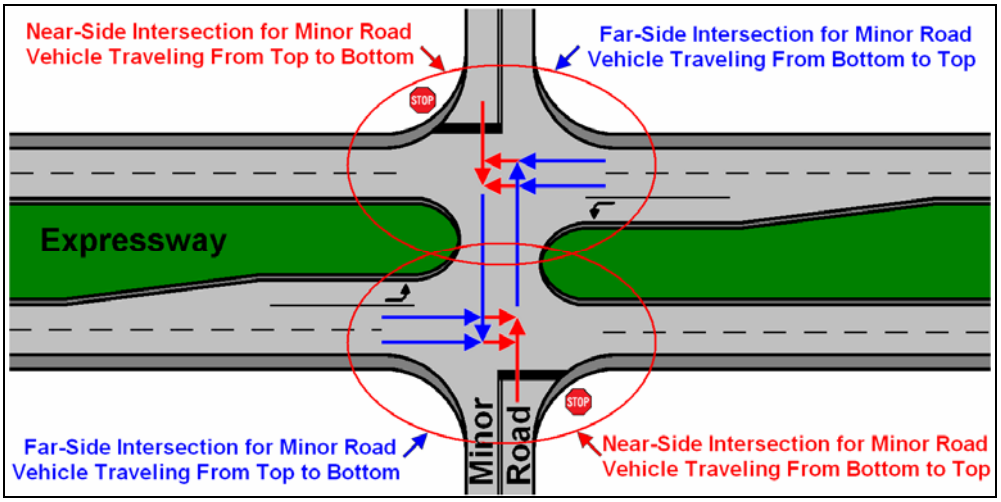


**Figure 1. Typical rural expressway at-grade intersection**

## PROBLEM STATEMENT

The purpose of providing exclusive right-turn lanes on expressway intersection approaches is to remove the deceleration and storage of right-turning vehicles from the through traffic lanes, thereby enabling through traffic to pass by with little conflict or delay and improving the overall safety and capacity of the intersection (AASHTO 2004). It is generally thought that the presence of exclusive right-turn lanes on the divided highway contributes to intersection safety by reducing speed differentials in the through lanes, consequently diminishing the potential for rear-end collisions, particularly on high-speed, high-volume approaches where right-turn volumes are substantial. However, the limited research assessing the safety effects of providing right-turn lanes at rural expressway/divided highway intersections revealed that conventional right-turn lanes may actually increase crashes (Maze, Hawkins, and Burchett 2004; Van Maren 1980).

A crash model developed by Van Maren (1980) for 39 randomly selected multilane divided highway intersections in rural Indiana showed that intersection crash rates increased with the presence of a right-turn deceleration lane on the divided highway. In a more recent study, a rural expressway intersection safety performance function developed by Maze, Hawkins, and Burchett (2004) using 644 TWSC expressway intersections in rural Iowa revealed a similar trend. Although this result was statistically significant, the authors speculated that the higher crash rates at locations with right-turn lanes was not due directly to their presence, but was instead due to the fact that right-turn lanes had been installed at high crash locations. However, another explanation of these findings might be that vehicles using a conventional right-turn lane to exit the expressway are obstructing the adjacent minor road driver's view of oncoming expressway traffic, as shown in Figure 2. This can lead to an increase in collisions involving vehicles turning left, turning right, or crossing from the minor road, thus creating a more dangerous intersection environment.

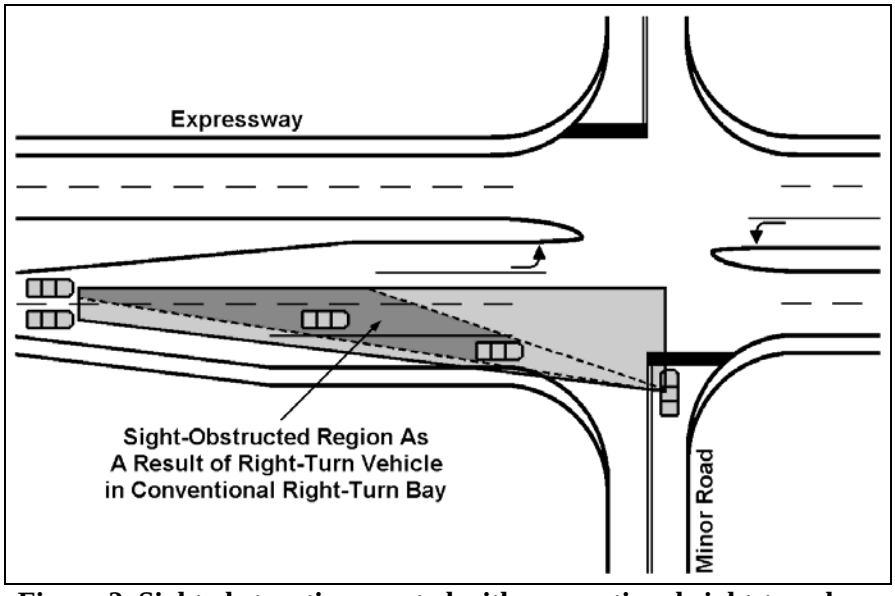


**Figure 2. Sight obstruction created with conventional right-turn lane**

The offset right-turn lane design alternative shown in Figure 3 helps to alleviate the sight distance obstruction created by the presence of right-turning vehicles in a conventional right-turn lane. In this design, the right-turn lane is moved laterally to the right as far as necessary so that right-turning vehicles no longer obstruct the view of minor road drivers positioned at the adjacent stop bar. Offset right-turn lanes should improve rural expressway intersection safety by enhancing intersection sight distance and

making it easier for minor road drivers to select safe gaps in the near-side expressway traffic stream. As such, they are expected to reduce near-side right-angle collisions between vehicles turning or crossing from the minor road and through vehicles on the divided highway; however, no research has been conducted to determine the safety benefits of applying this strategy at rural expressway intersections (Neuman et al. 2003).

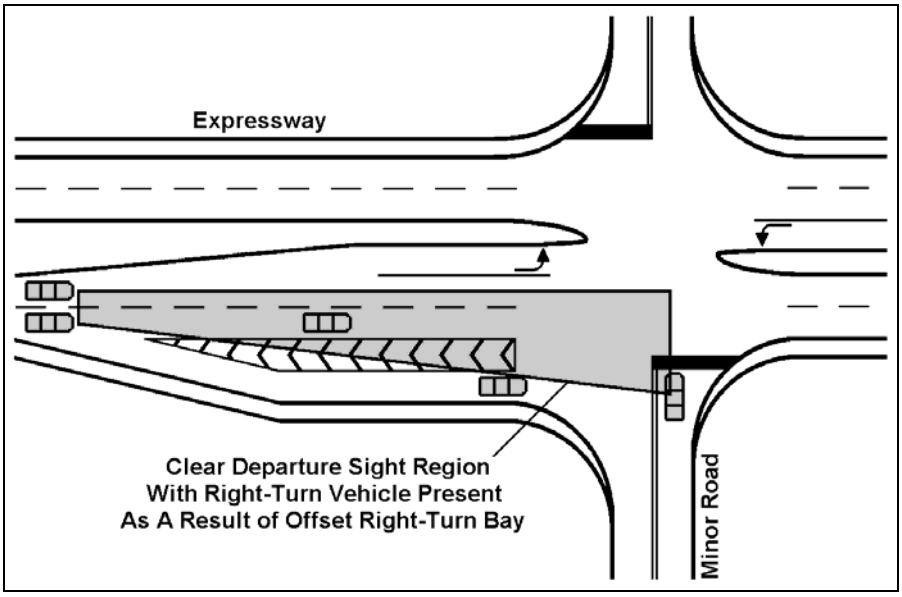


**Figure 3. Offset right-turn lane design concept**

## RESEARCH OBJECTIVES

STAs have experimented with a wide range of intersection safety treatments at problematic rural expressway intersections to improve their safety performance while avoiding costly grade separation. However, a recent survey of STAs conducted by Maze, Hawkins, and Burchett (2004) revealed that only five of the twenty-eight responding agencies had used offset right-turn lanes as a corrective measure at rural expressway intersections. This is probably due to the fact that no guidance on the use or design of offset right-turn lanes is provided in the AASHTO Green Book (2004). In addition, no studies have been conducted to determine the crash reduction potential of this strategy. Therefore, the objective of this research is to investigate the safety effectiveness of the offset right-turn lane design alternative. Examples of offset right-turn lane implementation were found in Iowa and Nebraska, and these case studies are presented herein.

## BEFORE-AFTER CRASH DATA ANALYSIS

### US-61 and Hershey Road, Muscatine, IA

Two examples of offset right-turn lane installations on rural expressways were found in Iowa. The first example is located at the intersection of US-61 and Hershey Road near the western edge of Muscatine, IA. An aerial photo of this intersection is shown in Figure 4. US-61 through this area was originally built to expressway standards in 1984. The construction of the US-61/Hershey Road intersection that resulted from this project did not provide any right-turn lanes for vehicles exiting US-61. The intersection remained this way until July of 2003, when offset right-turn lanes were installed on both the northbound and southbound US-61 approaches. Photographs of each offset right-turn lane are shown in Figure 5.

Subsequently, the intersection was signalized in November of 2005 and remains that way today. However, this intersection has been a consistent safety problem and is likely to be converted to an interchange sometime in the near future.

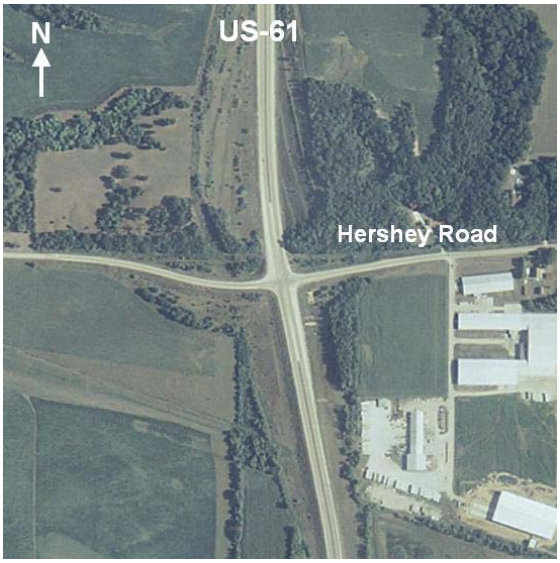


**Figure 4. Intersection of US-61 and Hershey Road, Muscatine, IA**


**Figure 5. Offset right-turn lanes installed at US-61 and Hershey Road, Muscatine, IA**

Before-after crash data for this offset right-turn lane implementation was obtained from the Iowa Traffic Safety Data Service (ITSDS) and is shown in Table 1. In the 3 1/2 year before period (January 1, 2000 through June 30, 2003), the intersection experienced a total of 15 intersection-related crashes (1 fatal, 10

injury, and 4 property damage-only [PDO]), giving an average crash frequency of 4.3 crashes per year. In the 2 1/4 year after period (August 1, 2003 through October 31, 2005), there were a total of 11 intersection-related crashes (2 fatal, 5 injury, and 4 PDO), resulting in an average of 4.9 crashes per year; an overall increase of 14%. However, in order to gauge the true effectiveness of the offset right-turn lane installation, a closer examination of the crash types targeted by the improvement, namely near-side right-angle collisions, is necessary (Neuman et al. 2003).

**Table 1. Before-after crash data for offset right-turn lanes at US-61 and Hershey Road**

| Data category | Before | After | % Change |
|---|---|---|---|
| Years | 3.50 | 2.25 | |
| Total intersection-related crashes | 15 | 11 | |
| Crash frequency/year | 4.29 | 4.89 | +14.1 |
| Fatal | 1 (0.29) | 2 (0.89) | +211.1 |
| Injury | 10 (2.86) | 5 (2.22) | -22.2 |
| PDO | 4 (1.14) | 4 (1.78) | +55.6 |
| Right-angle/broadside | 13 (3.71) | 9 (4.00) | +7.7 |
| Left turn leaving | 2 (0.57) | 0 (0.00) | -100 |
| Rear-end | 0 (0.00) | 2 (0.89) | +Infinite |
| Near-side right-angle | 6 (1.71) | 6 (2.67) | +55.6 |
| Far-side right-angle | 7 (2.00) | 3 (1.33) | -33.3 |
| % Near-side/right-angle | 46.15 | 66.67 | +44.4 |
| % Near-side/total crashes | 40.00 | 54.55 | +36.4 |

Note: Values in parenthesis are the average crash frequencies per year and were used to compute the percent change. Statistical analysis was not performed because there were less than three years of after data.

Because offset right-turn lanes are meant to reduce near-side right-angle collisions, and because offset right-turn lanes were installed on both mainline approaches at this location, a before-after comparison of total near-side right-angle collisions was conducted. In the before period, this site averaged 1.71 near-side right-angle collisions per year. In the after period, the site averaged 2.67 near-side right-angle collisions per year, an increase of approximately 56%. In both the before and after periods, this site averaged approximately four right-angle crashes per year; therefore, it appears that after the installation of the offset right-turn lanes, the distribution of far-side versus near-side crashes switched in favor of near-side crashes, which is an unexpected outcome.

Because there were two offset right-turn lanes installed at this location, one on northbound US-61 and one on southbound US-61, a separate analysis of near-side right-angle collisions was conducted for each offset right-turn lane. The results of this analysis are shown in Table 2. Table 2 shows that neither offset right-turn lane was effective in reducing the frequency of near-side right-angle collisions at this location. In both the before and after periods, five of the six near-side right-angle crashes involved southbound traffic on US-61 colliding with eastbound traffic on Hershey Road. This distribution can possibly be explained by the fact that southbound traffic on US-61 is rounding a horizontal curve and coming down a relatively steep grade as it approaches Hershey Road. These alignment issues could be causing eastbound drivers on Hershey Road to have problems seeing and/or judging the speed of southbound traffic on US-61, regardless of the presence of the offset right-turn lane. The view of an eastbound driver on Hershey Road can be seen in the top portion of Figure 5. These alignment issues may explain why the southbound offset right-turn lane was not beneficial; however, they do not explain why the northbound offset was ineffective.

**Table 2. Before-after analysis of individual offset right-turn lanes at US-61 and Hershey Road**

| Data category | Before | After | % Change |
|---|---|---|---|
| Years | 3.50 | 2.25 | |
| Southbound offset right-turn lane; near-side right-angle (SB and EB traffic) | 5 (1.43) | 5 (2.22) | +55.6 |
| Northbound offset right-turn lane; near-side right-angle (NB and WB traffic) | 1 (0.29) | 1 (0.44) | +55.6 |

Note: Values in parenthesis are the average crash frequencies per year and were used to compute the percent change. Statistical analysis was not performed because there were less than three years of after data.

Another issue at this intersection which may explain why both the northbound and southbound offset rights were ineffective is that the median width is very narrow (14–16 ft.). This geometry does not allow a minor road passenger car to be stored fully within the median; therefore, minor road drivers are forced to make a one-stage crossing or left-turn maneuver. As a result, the crossing/left-turning task for the minor road driver becomes increasingly complex, as they must simultaneously search for an acceptable gap in expressway traffic coming from both the left and the right.

**West Junction of US-18 and US-218, Floyd, IA**

The second example of an offset right-turn lane installation on a rural expressway in Iowa was found at the west junction of US-18 and US-218, just to the south of Floyd, IA. An aerial photo of this intersection is shown in Figure 6. US-18 was originally built to expressway standards sometime during the 1990s. The construction of the US-18/US-218 intersection that resulted from this project included a conventional right-turn lane for northwest-bound traffic on US-18 turning right onto US-218 toward Floyd. The intersection remained this way until late September of 2003, when Iowa Department of Transportation District 2 converted this conventional right-turn lane into an offset right-turn lane, as shown in Figure 7.


**Figure 6. West junction of US-18 and US-218, Floyd, IA**


**Figure 7. Offset right-turn lane at west junction of US-18 and US-218, Floyd, IA**

The offset right-turn lane at this intersection was installed due to a heavy volume of truck traffic exiting US-18 to access the truck stop located in the north quadrant of this intersection. The offset right-turn lane was constructed with district maintenance funds, and the intent was to keep the cost of the improvement to a minimum; therefore, the offset right-turn lane was designed as a normal parallel right-turn lane that flares out at a 30:1 taper in order to achieve the desired offset. During the design process, a minimum departure sight triangle was determined and used to decide how much the right-turn lane needed to be offset. However, during pavement marking, a decision was made in the field to extend the 2 ft. paved shoulder on the mainline throughout the offset right-turn lane. As a result, the outer edge of the gore area was painted 12 ft. from the striped right-turn lane edge-line, and the offset distance was reduced in size from what the designers had initially intended. As these markings wore off over time, the district attempted to increase the size of the offset (gore area) by positioning the right-turn lane closer to the edge of pavement. David Little, Assistant District 2 Engineer, stated, "The offset seems to have been an improvement, but the overall consensus is that the right-turn lane is still not offset far enough." Therefore, District 2 is currently working on a project that will offset this right-turn lane by 3 or 4 more ft. In conjunction with this project, the district plans to place rumble strips within the gore area to encourage right-turning drivers to use the full offset. Another means of increasing the offset at this location may also include moving the stop bar, stop sign, and divisional island on southwest bound US-218 closer to the mainline. Currently, they are positioned too far back (as shown in Figure 8), and as a result minor road drivers stopped at the stop bar do not get the full sight distance advantage provided by the offset right-turn lane.

Before-after crash data for this offset right-turn lane conversion was obtained from ITSDS and is shown in Table 3. In the 3 3/4 year before period (January 1, 2000 through September 24, 2003), the intersection experienced a total of 10 intersection-related crashes (6 injury, 4 PDO), giving an average crash frequency of 2.7 crashes per year. In the 2 1/4 year after period (October 15, 2003 through December 31, 2005), there were a total of 6 intersection-related crashes (all injury), resulting in an equivalent crash frequency of 2.7 crashes per year. Therefore, on the surface, it appears that the offset right-turn lane

installation at this location made no difference at all. However, an examination of near-side right-angle collisions (the crash type targeted by the improvement) shows much more positive results.


**Figure 8. Stop bar location on southwest bound US-218**

**Table 3. Before-after crash data for offset right-turn lane at west junction of US-18 and US-218**

| Data category | Before | After | % Change |
|---|---|---|---|
| Years | 3.73 | 2.21 | |
| Total intersection-related crashes | 10 | 6 | |
| Crash frequency/year | 2.68 | 2.71 | +1.14 |
| Fatal | 0 (0.00) | 0 (0.00) | 0 |
| Injury | 6 (1.61) | 6 (2.71) | +68.6 |
| PDO | 4 (1.07) | 0 (0.00) | -100 |
| Right-angle/broadside | 8 (2.14) | 2 (0.90) | -57.9 |
| Left-turn leaving | 1 (0.27) | 0 (0.00) | -100 |
| Rear-end | 1 (0.27) | 0 (0.00) | -100 |
| Right-turn leaving | 0 (0.00) | 3 (1.36) | +Infinite |
| Sideswipe (same direction) | 0 (0.00) | 1 (0.45) | +Infinite |
| Near-side right-angle | 6 (1.61) | 2 (0.90) | -43.8 |
| Far-side right-angle | 2 (0.54) | 0 (0.00) | -100 |
| % Near-side/right-angle | 75.00 | 100.00 | +33.3 |
| % Near-side/total crashes | 60.00 | 33.33 | -44.4 |

Note: Values in parenthesis are the average crash frequencies per year and were used to compute the percent change. Statistical analysis was not performed because there were less than three years of after data.

In the before period, this intersection experienced a total of 8 right-angle collisions. Of these 8, 6 were near-side collisions involving vehicles on southwest-bound US-218 colliding with vehicles on northwest-bound US-18 (the approach where the offset right-turn lane was eventually installed), giving a "preventable" near-side right-angle crash frequency of 1.61 crashes per year. In the after period, only two near-side right-angle crashes occurred that involved vehicles on southwest US-218 and northwest US-18, giving a near-side right-angle crash frequency of 0.90 per year and an overall near-side right-angle crash reduction of approximately 44%. Therefore, according to this naïve before-after crash data comparison, it appears that the offset right-turn lane installation at this location has been a safety improvement in terms of reducing near-side right-angle collisions. However, it is interesting to note that in the after period, there were three "right-turn leaving" crashes involving a right-turning vehicle on northwest US-18 that used the offset right-turn lane, turned at a high rate of speed, lost control, slid through the intersection, and collided with a vehicle on southwest US-218 that was stopped at the stop sign waiting to enter the intersection. This unexpected consequence may be an indication that drivers are interpreting the tapered offset right-turn lane design used at this location as a high-speed right-turn exit ramp, which is consequently encouraging drivers to make the right-turn at a higher rate of speed than is safe for the conditions. Some possible fixes to correct this problem include (1) paving the shoulder adjacent to the offset right-turn lane to keep excess gravel out of the turning lane, (2) increasing the turning radius for the exiting offset right-turn lane, (3) using a parallel offset right-turn lane design (see Figure 3) as opposed to the tapered type design used by the Iowa DOT (see Figures 5 and 7), and (4) posting an advisory speed plaque with the message "EXIT XX MPH" along the deceleration lane far enough in advance so that the exiting driver can make a safe slowing and turning maneuver.

**N-2 and 148th Street, Lincoln, NE**

A third example of an offset right-turn lane installation on a rural expressway was found at the intersection of Nebraska Highway 2 (N-2) and 148th Street, located a few miles to the southeast of Lincoln, Nebraska. The conversion of N-2 from a two-lane undivided highway to expressway standards was completed in late 1997. An aerial photo of the N-2/148th Street intersection that resulted from this project is shown in Figure 9. This initial design did not provide any right-turn lanes for traffic exiting N-2.


**Figure 9. Intersection of N-2 and 148th Street, near Lincoln, NE**

In late 1998, an NDOR traffic engineering study identified the need to install a right-turn lane on westbound N-2 for traffic turning northward onto 148th Street. 148th Street is a two-lane undivided paved county road that essentially functions as a bypass on the east edge of Lincoln, NE. The study indicated that (1) current right-turn traffic volumes at the intersection met NCHRP 279 (Neuman 1985) volume warrants for a full-width right-turn lane, (2) westbound right-turning traffic often used the paved shoulder to complete the turn, (3) a heavy volume of truck traffic was using 148th Street, and (4) although intersection sight distance was adequate, the intersection is placed on a crest vertical curve such that westbound traffic on N-2 does not see the intersection until just over the crest. As a result of these observations, a decision was made to construct an offset right-turn lane. The parallel offset right-turn lane, shown in Figure 10, was constructed and opened to traffic in late June 2003. NDOR personnel estimated that the offset distance is 12 ft. In addition, a divisional (splitter) island was installed on southbound 148th Street, and an additional stop sign was placed there, as shown in the lower portion of Figure 10.


**Figure 10. Offset right-turn lane at N-2 and 148th Street, near Lincoln, NE**

Crash data for this intersection was obtained from NDOR and is summarized in Table 4. In the 5 1/2 year before period (January 1, 1998 to June 30, 2003), there were a total of three reported PDO crashes that occurred at the intersection. Therefore, the average crash frequency was 0.55 crashes per year (recall that the offset right-turn lane installation at this location was based on a volume warrant, not poor safety performance). In the 2 1/2 year after period (July 1, 2003 to December 31, 2005), there were a total of five intersection-related collisions (1 fatal, 4 PDO), giving an average crash frequency of 2.0 crashes per year. Therefore, the crash frequency at this intersection increased by approximately 267% after the offset right-turn lane was installed; however, a further examination of near-side right-angle crashes shows more positive results.

**Table 4. Before-after crash data for offset right-turn lane at N-2 and 148th Street**

| Data category | Before | After | % Change |
|---|---|---|---|
| Years | 5.5 | 2.5 | |
| Total intersection-related crashes | 3 | 5 | |
| Crash frequency/year | 0.55 | 2.00 | +266.7 |
| Fatal | 0 (0.00) | 1 (0.40) | +Infinite |
| Injury | 0 (0.00) | 0 (0.00) | 0 |
| PDO | 3 (0.55) | 4 (1.60) | +193.3 |
| Right-angle/broadside | 2 (0.36) | 1 (0.40) | +10.0 |
| Rear-end | 1 (0.18) | 3 (1.20) | +560.0 |
| Other | 0 (0.00) | 1 (0.40) | +Infinite |
| Near-side right-angle | 1 (0.18) | 0 (0.00) | -100.0 |
| Far-side right-angle | 1 (0.18) | 1 (0.40) | +120.0 |
| % Near-side/right-angle | 50.00 | 0 | -100.0 |
| % Near-side/total crashes | 33.33 | 0 | -100.0 |

Note: Values in parenthesis are the average crash frequencies per year and were used to compute the percent change. Statistical analysis was not performed because there were less than three years of after data.

Of the three crashes that occurred during the before period, only one was a near-side right-angle collision involving a vehicle on southbound 148th Street colliding with a westbound vehicle on N-2 (the approach where the offset right-turn lane was eventually installed), giving a near-side right-angle crash frequency of 0.18 crashes per year. It was noted in the crash report that the southbound driver's sight distance was obstructed by an uninvolved right-turning vehicle on N-2; therefore, this collision may have been prevented had the offset right-turn lane been in place at that time. In the after period, even though the overall crash frequency dramatically increased, no near-side right-angle crashes occurred at the intersection, giving a 100% reduction for this crash type. Therefore, it appears that the offset right-turn lane was a safety improvement in terms of preventing near-side right-angle collisions. However, it should be mentioned that the collision classified as "other" in the after period was a single-vehicle, run-off-road, PDO crash under daylight and dry conditions in which a westbound vehicle on N-2 took evasive action to prevent a near-side right-angle collision with a southbound vehicle on 148th Street, which had pulled out in front of the westbound vehicle. It was not stated whether a right-turning vehicle was present at the time of this collision.

## CONCLUSIONS

The assumed safety benefit of offset right-turn lanes is that they eliminate the sight distance obstruction created by the presence of right-turning expressway vehicles positioned in a conventional right-turn lane, thereby allowing minor road drivers to make better gap acceptance decisions when entering the near-side intersection. Expressway intersections most likely to benefit from offset right-turn lanes include (1)

intersections with a history of near-side right-angle collisions resulting from right-turning expressway vehicles obstructing minor road driver sight lines and (2) intersections with large right-turn volumes (especially trucks) leaving the expressway, in combination with large volumes of minor road and expressway traffic on the corresponding approaches.

Two of the three before-after case studies presented here revealed a reduction in the frequency of near-side right-angle collisions, while the overall crash frequency at each intersection increased. Table 5 summarizes these results. However, the naïve before-after comparison approach used has two major limitations. First, it does not take regression to the mean into account. (I.e., because two of the three sites were high-crash locations, there would likely have been a reduction in crashes during the after period even if nothing had been done due to simple chance). Second, it is not known what part of the change in safety can be attributed to the treatment and what part is due to various other influences, such as changes in traffic volume, vehicle fleet mix, weather, driver behavior, etc. Finally, it must also be stated that offset right-turn lanes are only meant to enhance sight distance and reduce the possibility of near-side collisions when right-turning vehicles are present. By only examining the crash data, there is no way of knowing whether or not right-turning vehicles were present at the time of these collisions. Therefore, a better means of determining the safety effectiveness of the offset right-turn lane treatment may be to conduct an observational before-after conflict analysis.

**Table 5. Offset right-turn lane safety effectiveness summary**

| | % Change | | |
|---|---|---|---|
| | **US-61 and Hershey Rd.** | **US-18 and US-218** | **N-2 and 148th St.** |
| Total crash frequency | +14 % | +1 % | +267 % |
| Right-angle crash frequency | +8 % | -58 % | +10 % |
| Near-side right-angle Crash frequency | +56 % | -44 % | -100 % |

Note: Statistical analysis was not performed because there were less than three years of after crash data in each case.

Given the limited number of sites, the fact that there were less than three years of after data at each site, and the limitations of the naïve before-after analysis, the specific results shown in Table 5 may not be transferable to other expressway intersections. However, the lessons learned from these case studies are important for other STAs to take away as they begin to implement this countermeasure.

Offset right-turn lane design guidance should be included in the AASHTO Green Book (2004). The most important design aspect of an offset right-turn lane is that it should provide the minor road driver with a clear departure sight triangle to the left (i.e., sufficient sight distance along the near-side expressway lanes) when right-turning vehicles are present on the mainline. Meeting this design criterion should aid minor road drivers in judging the suitability of available gaps in the near-side expressway traffic stream when making turning or crossing maneuvers. The recommended dimensions for the legs of a clear departure sight triangle are described in Chapter 9 of the AASHTO Green Book (2004). The required right-turn offset distance may vary from intersection to intersection based on each intersection's unique geometry (skew, horizontal curvature, approach grades, design speed, stop bar placement, etc.); therefore, intersection design plans should be checked to ensure that adequate intersection sight distance is provided. In addition, rumble strips may be placed in the gore area to ensure that the offset right-turn lane is used properly, and additional precautions should be taken to prevent "right-turn leaving" collisions.

## ACKNOWLEDGMENTS

This research was conducted as part of active project NCHRP 15-30, "Median Intersection Design for Rural High-Speed Divided Highways."

The authors would like to thank the following individuals for providing crash data and other pertinent information regarding the offset right-turn lane installations discussed herein:

- Peter Tollenaere, Assistant District Engineer, Iowa DOT District 5
- David Little, Assistant District Engineer, Iowa DOT District 2
- Mark Brandl, Davenport Resident Construction Engineer
- Michael Pawlovich, Crash Data Engineer, Iowa Department of Transportation Office of Traffic and Safety
- Vic Lund, Iowa Traffic Safety Data Service
- Dave Peterson, Nebraska Department of Roads Traffic Engineering Division

## REFERENCES

AASHTO. 2004. *A Policy on Geometric Design of Highways and Streets, Fifth Edition*. Washington, DC: American Association of State Highway and Transportation Officials.

Maze, T.H., N.R. Hawkins, and G. Burchett. 2004. *Rural Expressway Intersection Synthesis of Practice and Crash Analysis.* Final Report. CTRE Project 03-157. Ames, IA: Center for Transportation Research and Education. http://www.ctre.iastate.edu/reports/expressway.pdf

Harwood, D.W., M.T. Pietrucha, M.D. Wooldridge, R.E. Brydia, and K. Fitzpatrick. 1995. *National Cooperative Highway Research Program Report 375: Median Intersection Design.* T Washington, DC: Transportation Research Board, National Research Council.

NDOR. 2000. *Accident Experience of Rural Highways: Two-Lane vs. Four-Lane Expressways*. Highway Safety Division, Nebraska Department of Roads. Unpublished.

Preston, H., R. Storm, M. Donath, and C. Shankwitz. 2004. *Review of Minnesota's Rural Intersection Crashes: Methodology for Identifying Intersections for Intersection Decision Support (IDS), Report #1: Developing Intersection Decision Support Solutions*. Report No. MN/RC-2004-31. St. Paul, MN: Minnesota Department of Transportation. http://www.its.umn.edu/research/applications/ids/consortium/publications/200431.pdf

Van Maren, P.A. 1980. *Correlation of Design and Control Characteristics with Accidents at Rural Multi-Lane Highway Intersections in Indiana.* Interim Report. FHWA-IN-JHRP-77-20. Purdue University and Indiana State Highway Commission Joint Highway Research Project.

Neuman, T.R., R. Pfefer, K.L. Slack, K.K. Hardy, D.W. Harwood, I.B. Potts, D.J. Torbic, and E.R.K. Rabbani. 2003. *National Cooperative Highway Research Program Report 500: Guidance for Implementation of the AASHTO Strategic Highway Safety Plan, Volume 5: A Guide for Addressing Unsignalized Intersection Collisions*. Washington, DC: Transportation Research Board, National Research Council. http://gulliver.trb.org/publications/nchrp/nchrp_rpt_500v5.pdf

Neuman, T.R. 1985. *National Cooperative Highway Research Program Report 279: Intersection Channelization Design Guide*. Washington, DC: Transportation Research Board, National Research Council.