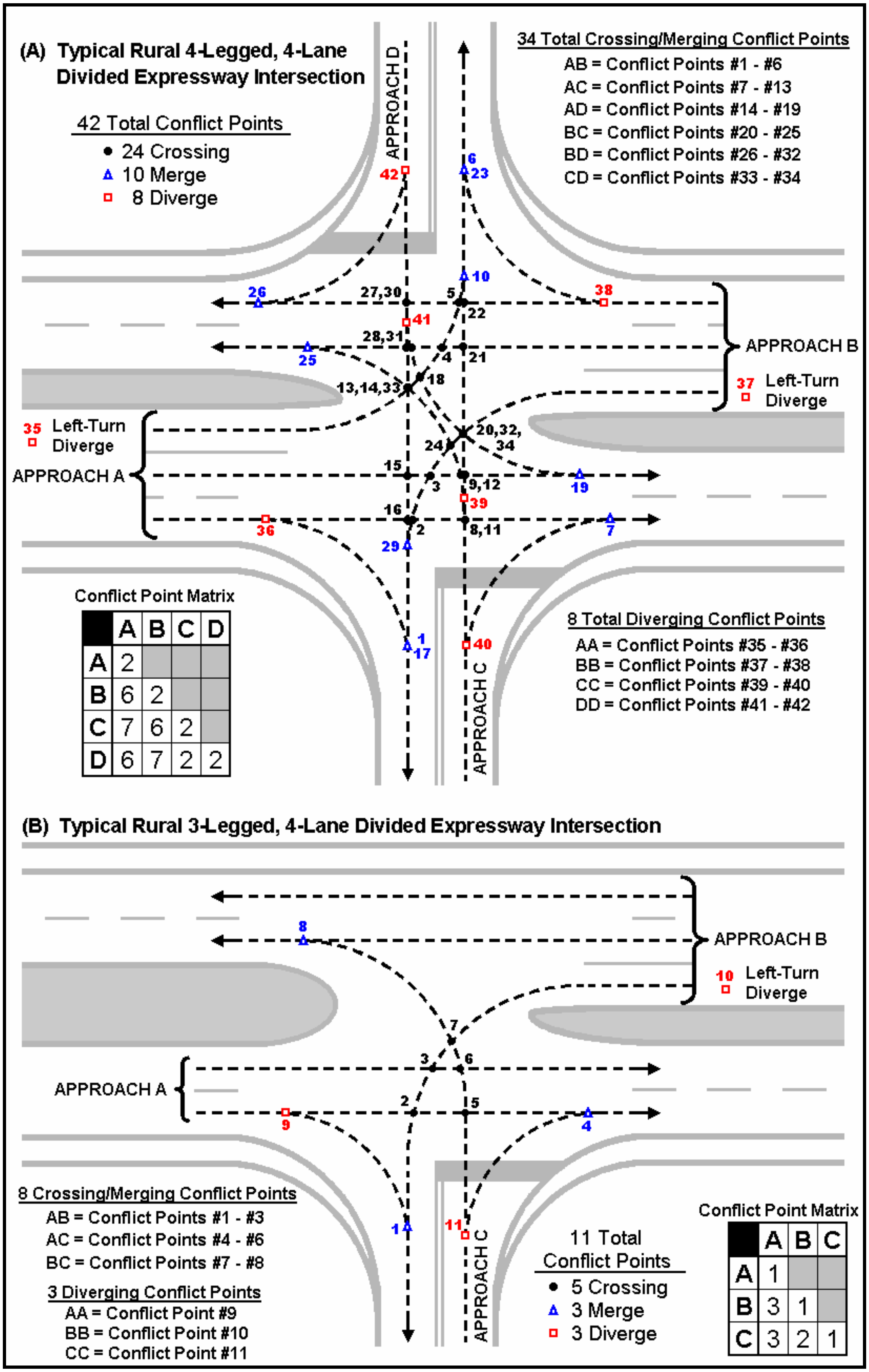
"Offset T-Intersections"

Background/Description

Regardless of signing and signalization, at-grade intersections have the potential for vehicle-vehicle collisions as a result of vehicular conflicts. Intersection conflict points represent the locations where vehicle paths meet as they move from one intersection leg to another. Intersection conflict point analysis is a well understood means of comparing the relative safety of alternative intersection designs (*1*). The basic premise suggests that the intersection safety performance will decline when the design results in more conflict points. This approach is useful, but is ultimately limited because it assumes that the crash risk is equal at each conflict point, when in fact, the crash risk associated with each conflict point varies depending on the complexity and volumes of the movements involved. The greatest crash risk movements (i.e., those accounting for the largest proportion of crashes) at a typical four-legged, two-way stop controlled (TWSC) rural expressway intersection are usually the minor road left-turn and crossing maneuvers (2). Therefore, elimination or minimization of these left-turning and crossing conflicts could be an effective means of improving safety at rural expressway intersections.

It has long been acknowledged that three-legged intersections operate more safely than comparable four-legged intersections because three-legged intersections have fewer conflict points (*1*). Figure 1A shows that a typical four-legged, four-lane rural expressway intersection has a total of 42 conflict points assuming that opposing left-turn paths do not overlap. A similar three-legged, T-intersection shown in Figure 1B has almost 75 percent fewer conflict points with only eleven. In addition to reducing the total number of conflict points, a three-legged intersection minimizes the maneuvers that have been observed to be over-represented in rural expressway intersection crashes (all crossing maneuvers from the minor road and one of the minor road left-turns are eliminated). Crash models developed in NCHRP 375 (*3*) verified that crash frequency and rates at rural, three-legged, unsignalized, divided highway intersections are substantially lower than at their four-legged counterparts. Therefore, converting four-legged intersections to three-legged intersections should improve rural expressway intersection safety.

When converting four-legged intersections to three-legged intersections, there are three different T-intersection designs that could be used: a typical T, a channelized T, or a continuous green T. These three T-intersection designs are illustrated in Figure 2. Further research is necessary to determine which of these designs performs best in terms of safety and operations; however, the continuous green T-intersection was developed specifically for T-intersections in which a minor collector roadway ends at a major highway (*4*). Hummer and Boone (*5*, *6*) have previously addressed some of the advantages and disadvantages associated with a signalized continuous green T-intersection in relation to its use on urban and suburban arterials. However, its application at a rural expressway intersection has not been examined.



	A	B	C	D
A	2			
B	6	2		
C	7	6	2	
D	6	7	2	2

	A	B	C
A	1		
B	3	1	
C	3	2	1

FIGURE 1 Comparison of Conflict Points at 4-Legged Versus 3-Legged Intersections.

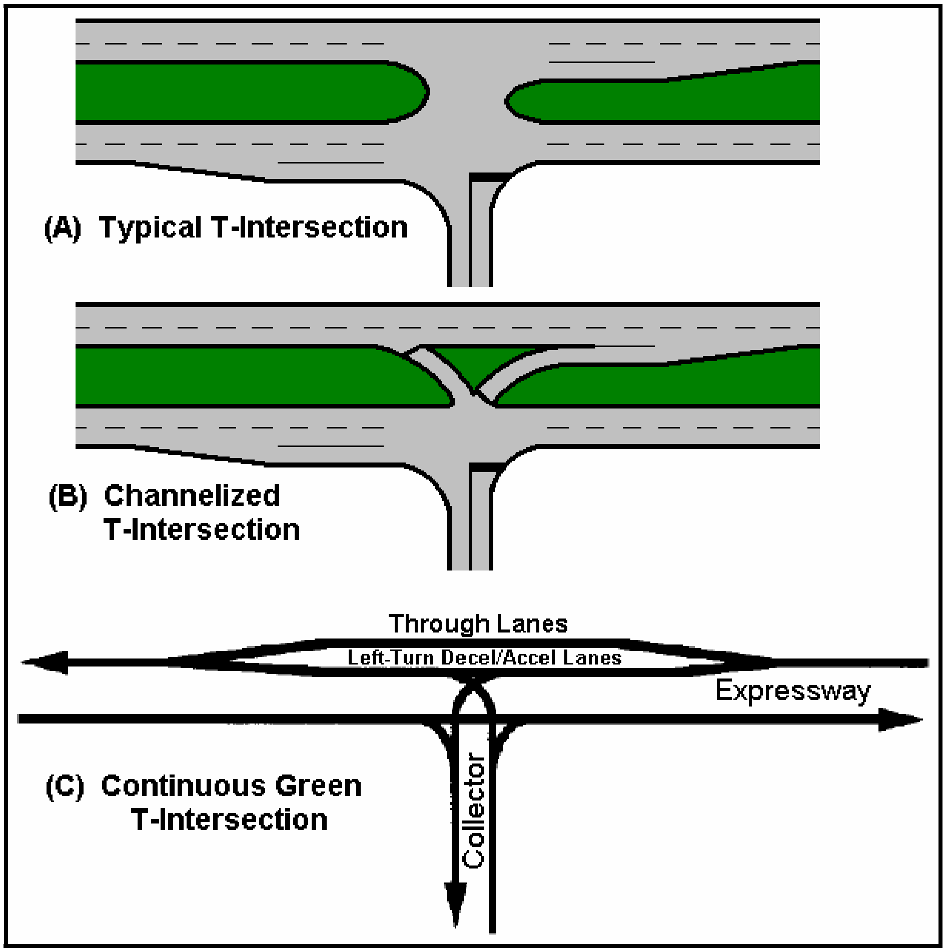


FIGURE 2 Types of T-Intersections.

With the conversion of a four-legged intersection into a three-legged intersection, adequate through access for minor road traffic can still be maintained by creating two T-intersections separated by an appropriate distance. This design, otherwise known as an "offset T-intersection", is illustrated in Figure 3A. Converting a four-legged expressway intersection into an offset T-intersection reduces the total number of conflict points from 42 to 26 and, according to Bared and Kaisar (*7*), the conversion is expected to reduce total crashes by 40 to 60 percent where design speeds on the expressway are greater than 50 mph and total entering traffic volumes are less than 25,000 vehicles per day. In addition, NCHRP 500 (*8*) states that this design option should work well if the through volumes emanating from the minor road are low (no volume threshold was indicated). If minor road through volumes are at higher levels, a "one-quadrant interchange" design, as shown in Figure 3B, may be justified instead.

The offset T-intersection design shown in Figure 3A is known as a "right-left" configuration because a through vehicle on the minor road must first turn right onto the expressway and then turn left off of it (*7*). The right-left configuration is preferred over a left-right configuration because the right-left configuration reduces the required number of high risk, left-turning maneuvers from the minor road. For ideal operation, the two T-intersections should be spaced far enough apart so that they will each operate independently, allowing a through vehicle on the minor road adequate space to merge across the expressway lanes and safely enter the opposite minor roadway without causing undue interference to through expressway traffic. For high-speed (65 mph) divided four lane roads, Bared and Kaisar (*7*) suggest that interference is minimized when the intersections are offset by 141 feet for a right-left configuration and 235 feet for a left-right configuration, although these distances seem very short. The minimum spacing between median openings currently used by DOTs in rural areas ranges from 500 feet to a half mile (*1*). These distances would seem more appropriate for offset spacing under high-speed expressway conditions.

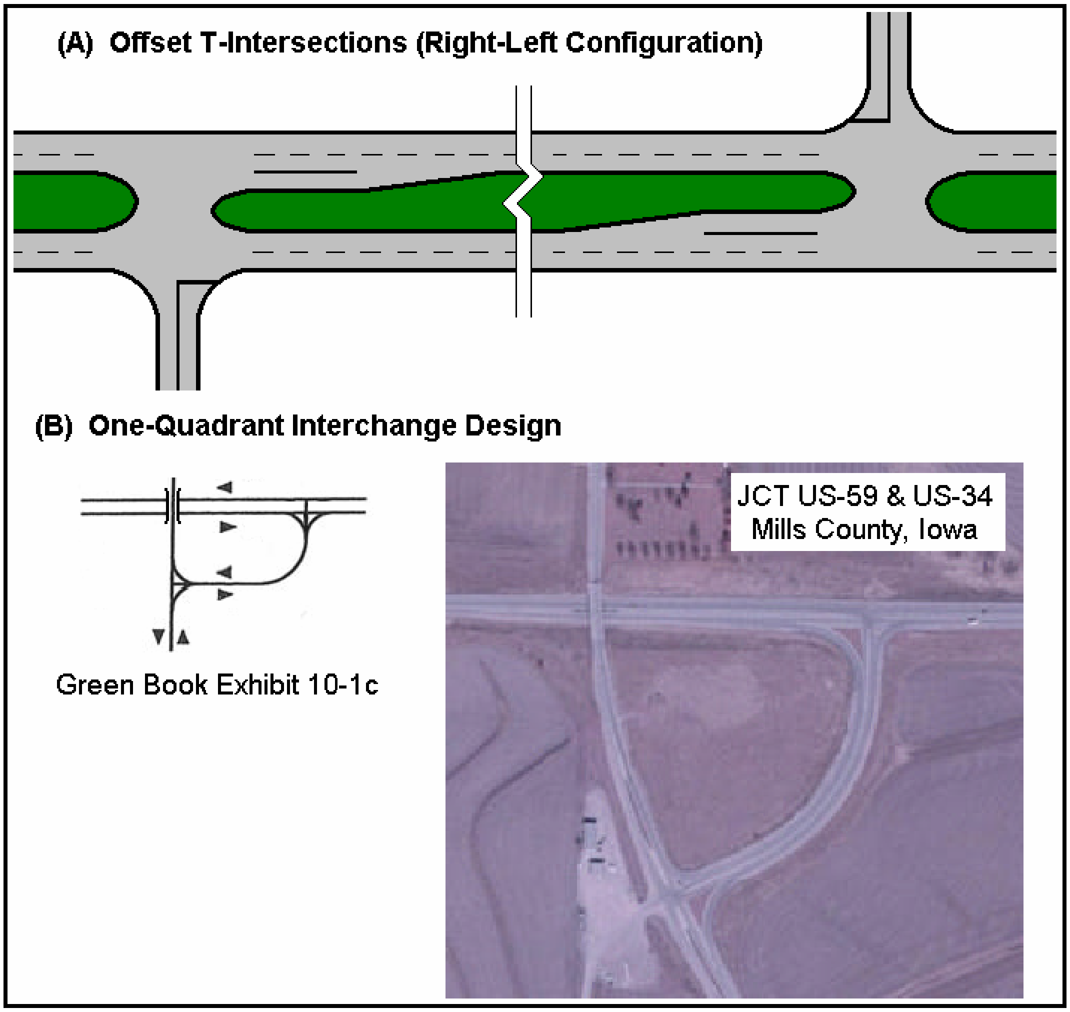


FIGURE 3 4-Leg to 3-Leg Alternative Designs to Accommodate Minor Through Traffic.

Clearly, the biggest issue with creating an offset T-intersection is acquiring the necessary right-of-way to allow the relocation of one of the minor roadway approach legs, especially if the land along the existing right-of-way is already in use. However, in rural areas, it may be problematic but possible to acquire additional right-of-way to create an offset T-intersection. Because retrofitting could prove to be difficult, identifying opportunities to create offset T-intersections should be part of the initial corridor development process. Additional disadvantages associated with the offset T-intersection design include increased travel time/distance and potential confusion for minor road through drivers.

Examples of Offset T-Intersection Implementation

Finding examples of offset T-intersections on rural expressways proved difficult for this case study. The first example of an offset T-intersection was found in a suburban location on the west side of Fort Dodge, Iowa. The intersection of US-169 (a four-lane divided highway) and Avenue G was converted from a four-legged intersection into a left-right offset T-intersection in November of 2002. Before and after aerial photos of the intersection are shown in Figure 4. A roadway level view of the after condition is shown in Figure 6. The offset distance is 1,500 feet.

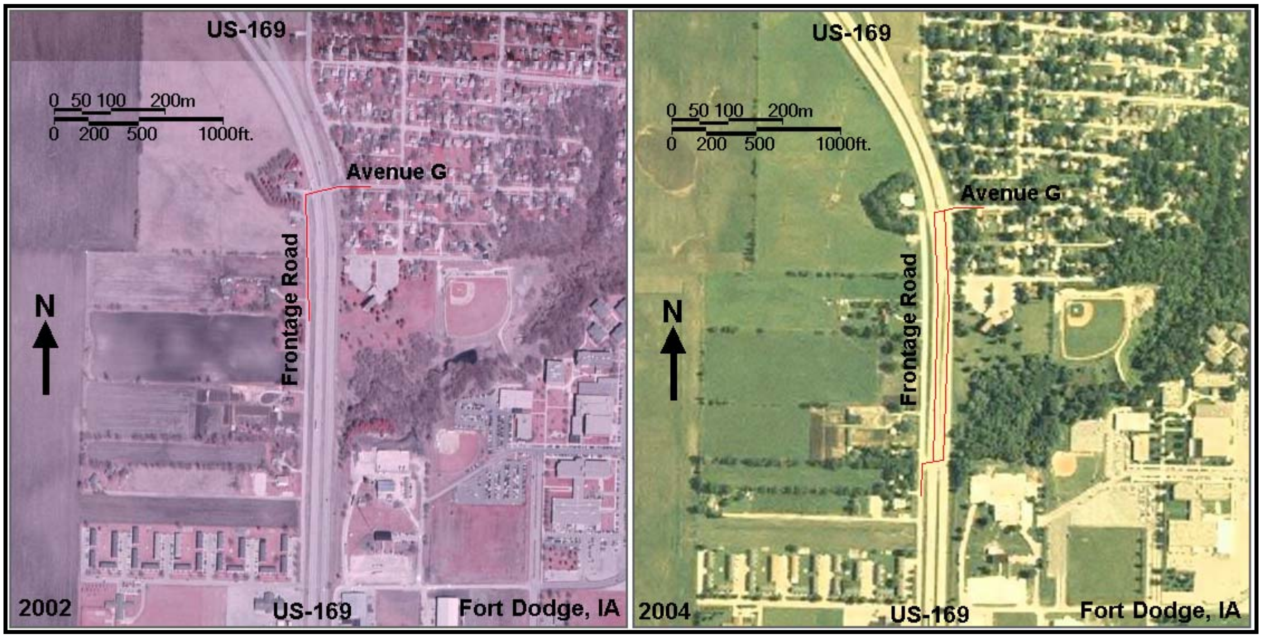


Figure 4 Offset T Application in Suburban Fort Dodge, Iowa

Figure 5 Looking North From South T-Intersection in Fort Dodge, IA

Before-after crash data for this conversion project was obtained from the Iowa Traffic Safety Data Service (ITSDS). The crash data is presented in Table 1. In the almost four-year before period (1999 – 2002), the four-legged intersection of US-169 and Avenue G averaged 3 crashes per year. In the just over three year after period (2002 – 2005), the two T-intersections combined to average 2 crashes per year. Therefore, the overall crash reduction of this offset T conversion project was approximately 30 percent, which is slightly less than what was estimated by Bared and Kaisar (*7*). In addition, right-angle crashes were reduced by 40 percent.

Table 1 Before-After Crash Data for Fort Dodge Offset T-Intersection Conversion

	YEAR	TOTAL	FATAL	INJURY	PDO	RIGHT-ANGLE	OTHER
BEFORE *	**1999**	4	1	3	0	4	0
	2000	4	0	0	4	2	2
	2001	2	0	1	1	2	0
	5/6 of 2002	2	0	1	1	2	0
	TOTAL	**12**	**1**	**5**	**6**	**10**	**2**
	AVE/YR	**3.13**	**0.26**	**1.30**	**1.57**	**2.61**	**0.52**
	YEAR	**TOTAL**	**FATAL**	**INJURY**	**PDO**	**RIGHT-ANGLE**	**OTHER**
AFTER **	**1/6 of 2002**	1	0	0	1	1	0
	2003	1	0	1	0	1	0
	2004	3	1	1	1	2	1
	2005	2	0	1	1	1	1
	TOTAL	**7**	**1**	**3**	**3**	**5**	**2**
	AVE/YR	**2.21**	**0.32**	**0.95**	**0.95**	**1.58**	**0.63**
	% CHANGE	**-29.4**	**+21.1**	**-27.4**	**-39.5**	**-39.5**	**+21.1**

* *The before period includes crash data at JCT US-169 & Ave. G (4-legged).*

** *The after period includes crash data at both north & south T-intersections.*

A second example of an offset T-intersection was found in Oregon at the junction of Oregon Highway 34 (OR-34) and Oakville Road, approximately 9 miles east of Corvallis, Oregon. In this area, OR-34 is a four-lane divided highway with a continuous flush median. Prior to 1995, the intersection of OR-34 and Oakville Road was a four-legged intersection. Sometime in 1995, the Oregon DOT converted this intersection into a right-left offset T-intersection with an offset distance of ¼ mile (1320 feet). Figure 6 illustrates some of the signage used along OR-34 in advance of this offset T configuration.

Figure 6 Oregon Offset T-Intersection Signage

Before-after crash data for this conversion project were provided by the Oregon DOT (ODOT) and are shown in Table 2. The data indicates that the conversion from a four-legged intersection into a right-left offset T configuration resulted in a 53 percent reduction in total crashes per year and a 72 percent reduction in fatal/severe injury crashes per year. Therefore, the overall crash reduction at this location is consistent with what was estimated by Bared and Kaisar (*7*).

Table 2 Before-After Crash Data for Oregon Offset T-Intersection Conversion

	YEAR	TOTAL	FATAL	SEVERE INJURY
BEFORE *	**1990**	5	0	3
	1991	1	0	0
	1992	4	0	2
	1993	7	1	1
	1994	2	0	1
	TOTAL	**19**	**1**	**7**
	AVE/YR	**3.80**	**0.20**	**1.40**
	YEAR	**TOTAL**	**FATAL**	**SEVERE INJURY**
AFTER **	**1996**	3	0	1
	1997	6	0	2
	1998	2	0	1
	1999	0	0	0
	2000	0	0	0
	2001	1	0	0
	2002	0	0	0
	2003	2	0	0
	2004	2	0	0
	TOTAL	**16**	**0**	**4**
	AVE/YR	**1.78**	**0.00**	**0.44**
	% CHANGE	**-53.2**	**-100**	**-68.3**

** Before crash data is for JCT OR-34 & Oakville Rd (4-leg).*
*** After crash data is for both east & west T-intersections.*

Outcomes and Lessons Learned

Nothing definitive can be concluded regarding the safety benefits of offset T-intersections through a sample of only three cases. However, the two cases cited only help reinforce the theory that safety benefits can be attained by converting four-legged rural expressway intersections into T-intersections. Table 3 summarizes the two offset T case studies reported here. It is impossible to conclude much of anything with only two data points but it is interesting that, as expected, a right-left configuration in Oregon resulted in a greater safety benefit than the left-right configuration in Iowa.

Table 3 Offset T-Intersection Case Study Summary

CASE STUDY	OFFSET CONFIGURATION	TOTAL CRASHES PER YEAR	TOTAL CRASH REDUCTION
Suburban Iowa	Left-Right	2.21	29%
Rural Oregon	Right-Left	1.78	53%

Because converting existing four-legged intersections into offset T's can be impractical in many situations, identifying opportunities to create offset T-intersections should be a part of the initial corridor planning process when rural two-lane undivided highways are being converted to divided expressways.

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