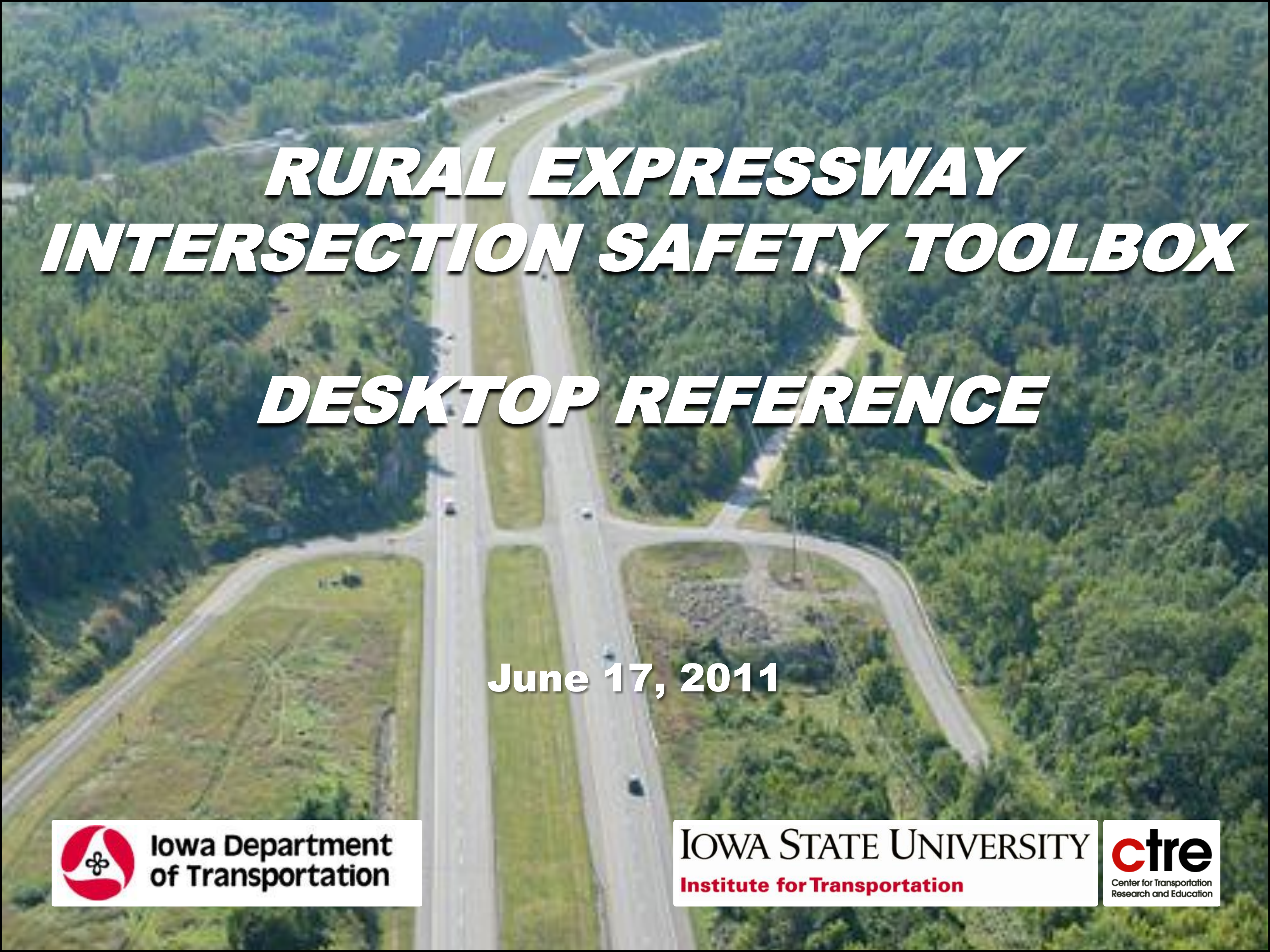

RURAL EXPRESSWAY INTERSECTION SAFETY TOOLBOX

DESKTOP REFERENCE

June 17, 2011

Iowa Department of Transportation

Iowa State University
Institute for Transportation

ctre
Center for Transportation Research and Education

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Joshua L. Hochstein
Chris Albrecht
Reginald R. Souleyrette

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Disclaimer & Background

- This document is intended to be a guide for planning-level decisions concerning safety issues and subsequent potential improvements at rural expressway intersections. It is NOT a design guide. It simply presents the gamut of safety treatment options and available strategies that have been employed in an attempt to reduce the number and severity of collisions at unsignalized rural expressway intersections.

- This document should only be used as a tool for considering safety treatment options at rural expressway intersections. It is meant to aid transportation agency management in selecting the most appropriate rural expressway treatment to address the particular safety issue they are facing.

- This document is a quick reference companion to the "Rural Expressway Intersection Safety Toolbox".[1] More details on each strategy can be found within the contents of that document.

- Treatment strategies have been categorized within 9 emphasis areas (A through I) similar to those within NCHRP 500, Volume 5 [2]; however, the focus here is directly on unsignalized rural expressway intersections rather than unsignalized intersections in general. Some strategies may qualify for multiple categories, but have been placed in the category judged to be the most applicable.

Definitions

- **Effectiveness**

  The effectiveness of the various strategies have been rated as either proven, tried, or experimental based on the NCHRP 500 Series[2] definitions given below:

  - **Proven (P)** = Strategies used in multiple locations for which properly designed safety evaluations have been conducted showing the treatment to be effective. These strategies may be employed with a good degree of confidence, but with the understanding that any application may lead to results that vary significantly from those found in previous evaluations.

  - **Tried (T)** = Strategies implemented at a number of locations and may even be accepted as standard practice, but for which there have NOT been found valid safety evaluations. While there can be some degree of assurance that implementation will not likely have a negative impact on safety, these strategies should be applied with caution. Users should carefully consider the “concerns addressed” and the “potential application” attributes and relate them to the specific site conditions for which they are being considered.

  - **Experimental (E)** = Strategies that have been suggested and at least one agency has tried on a small scale in at least one location. These strategies should only be considered after others have been determined to be inappropriate or unfeasible. Their implementation should initially occur using a very controlled and limited pilot study including a properly designed evaluation component.

- **Cost**

  Project costs will vary considerably and are affected by local conditions. Costs have been rated on a four-point scale of ***low, moderate, high, and extreme***. Specific dollar value ranges are not associated with these rankings. They are a general scale meant to reflect costs relative to the other treatments.

- **Time**

  Treatment implementation timeframes will also vary based on numerous factors. The three-point timeframe scale of ***short (< 1 Year), medium (1-2 Years), and long (> 2 Years)*** is provided as a general guide to reflect project timelines relative to the other treatments.

Treatment List

TREATMENT	EFFECTIVENESS	COST	TIME
A1: Close Low Volume Intersections & Connect via Frontage Roads	TRIED	MODERATE	MEDIUM
A2: Convert Single At-Grade Intersection to Interchange	PROVEN	EXTREME	LONG
A3: Convert Expressway Corridor to Freeway	PROVEN	EXTREME	LONG
B1: Convert Intersection to All-Way Stop Control	TRIED	LOW	SHORT
B2: Provide Signalization	TRIED	MODERATE	MEDIUM
C1: Provide or Lengthen Expressway Left/Right-Turn Deceleration Lanes	TRIED	MODERATE	MEDIUM
C2: Close Median Crossovers (Right-In, Right-Out Access Only)	TRIED	LOW	SHORT
C3: Convert to U-Turn Intersection	TRIED	MODERATE	MEDIUM
C4: Provide Directional Median Opening	TRIED	LOW	SHORT
C5: Convert to J-Turn Intersection (JTI)	TRIED	MODERATE	MEDIUM
C6: Convert to Offset T-Intersection	TRIED	HIGH	MEDIUM
C7: Convert to One-Quadrant Interchange	TRIED	EXTREME	LONG
D1: Provide Clear Sight Triangles from Stop-Controlled Approaches & the Median	TRIED	LOW	SHORT
D2: Move Minor Road/Median Stop/Yield Bars Closer to Expressway &/or Provide Dotted Edge Line Extensions	TRIED	LOW	SHORT
D3: Provide Offset Left-Turn Lanes	TRIED	MODERATE	MEDIUM
D4: Provide Offset Right-Turn Lanes	TRIED	MODERATE	MEDIUM
D5: Redesign Minor Road Right-Turn Channelization	EXPERIMENTAL	MODERATE	MEDIUM
D6: Realign Intersection Approaches to Reduce or Elliminate Skew	PROVEN	HIGH	MEDIUM
D7: Modify Horizontal/Vertical Alignment of Expressway Approaches	TRIED	EXTREME	LONG
E1: Roadside Markers/Poles	EXPERIMENTAL	LOW	SHORT
E2: Intersection Decision Support (IDS) Technology (Missouri DOT System)	EXPERIMENTAL	MODERATE	SHORT
E3: Intersection Decision Support (IDS) Technology (Minnesota DOT System)	EXPERIMENTAL	HIGH	MEDIUM
F1: Provide Right-Turn Acceleration Lanes	TRIED	MODERATE	MEDIUM
F2: Provide Left-Turn Median Acceleration Lanes (MALs)	TRIED	MODERATE	MEDIUM
G1: Median Delineation with Pavement Marking	TRIED	LOW	SHORT
G2: Median Signage	TRIED	LOW	SHORT
G3: Widen/Modify Expressway Median	TRIED	EXTREME	LONG
H1: Provide "Divided Highway" & "Cross Traffic Does Not Stop" Placards on Minor Road	TRIED	LOW	SHORT
H2: Provide Wrong-Way Entry Prevention Signage/Pavement Markings for Minor Road Traffic	EXPERIMENTAL	LOW	SHORT
H3: Provide Traditional "Stop Ahead" Warning Signs & Pavement Markings for Minor Road	TRIED	LOW	SHORT
H4: Provide Larger/More Reflective/Overhead/Flashing Approach Signage on Minor Road	TRIED	LOW	SHORT
H5: Provide In-Lane Rumble Strips on Minor Road	TRIED	LOW	SHORT
H6: Provide Divisional/Splitter Island at Mouth of Intersection on Minor Road	TRIED	MODERATE	MEDIUM
H7: Provide Traditional "Intersection Ahead" Warning Signs on Expressway	TRIED	LOW	SHORT
H8: Provide Enhanced Freeway-Style or Diagrammatic Advance Intersection Guide Signs on Expressway	TRIED	LOW	SHORT
H9: Provide "Watch For Entering Traffic" Dynamic Warning Signs & Flashers with/without Speed Advisory on Expressway	TRIED	LOW	SHORT
H10: Provide Intersection Lighting	PROVEN	HIGH	MEDIUM
I1: Expressway Speed Zoning Through Intersections	TRIED	LOW	SHORT
I2: Targeted Intersection Speed Enforcement	PROVEN	LOW	SHORT

CONCERNS ADDRESSED VS EFFECTIVENESS

	CONCERN ADDRESSED	EFFECTIVENESS: PROVEN	EFFECTIVENESS: TRIED	EFFECTIVENESS: EXPERIMENTAL
SAFETY	ALL RIGHT-ANGLE (25)	A2, A3, D6, H10, I2	A1, B1, B2, C1, C7, D1, D2, D7, H1, H3, H4, H5, H6, H7, H8, H9, I1	E1, E2, E3
SAFETY	FAR-SIDE RIGHT-ANGLE (10)		C2, C3, C4, C5, C6, D3, F2, G1, G2, G3	
SAFETY	NEAR-SIDE RIGHT-ANGLE (3)		D4, F1	D5
SAFETY	ALL REAR-END (8)	A2, A3, H10	A1, C7, D2, F1	D5
SAFETY	MAINLINE REAR-END (14)	I2	C1, D1, D3, D4, F2, H1, H7, H8, H9, I1	E1, E2, E3
SAFETY	MINOR ROAD REAR-END (4)		H3, H4, H5, H6	
SAFETY	LEFT-TURN LEAVING (16)	A2, A3, D6, H10, I2	A1, B1, C1, C2, C3, C4, C5, C7, D1, D3, I1	
SAFETY	MEDIAN COLLISIONS (15)	A2, A3, H10	A1, B1, B2, C2, C3, C4, C5, C6, C7, D3, G1, G3	
SAFETY	MAINLINE HEAD-ON COLLISIONS (3)	H10	H1	H2
DELAY	MINOR ROAD DELAY (17)	A2, A3, D6	B1, B2, C1, C7, D1, D2, D4, D7, F1, F2	D5, E1, E2, E3
DELAY	MEDIAN DELAY (15)	A2, A3	B1, B2, C1, C2, C3, C4, C5, C6, C7, F2	E1, E2, E3
DELAY	EXPRESSWAY DELAY (1)	A3		

CONCERNS ADDRESSED VS COST

	CONCERN ADDRESSED	COST: LOW	COST: MODERATE	COST: HIGH	COST: EXTREME
SAFETY	ALL RIGHT-ANGLE (25)	B1, D1, D2, E1, H1, H3, H4, H5, H7, H8, H9, I1, I2	A1, B2, C1, E2, H6	D6, E3, H10	A2, A3, C7, D7
SAFETY	FAR-SIDE RIGHT-ANGLE (10)	C2, C4, G1, G2	C3, C5, D3, F2	C6	G3
SAFETY	NEAR-SIDE RIGHT-ANGLE (3)		D4, D5, F1		
SAFETY	ALL REAR-END (8)	D2	A1, D5, F1	H10	A2, A3, C7
SAFETY	MAINLINE REAR-END (14)	D1, E1, H1, H7, H8, H9, I1, I2	C1, D3, D4, E2, F2	E3	
SAFETY	MINOR ROAD REAR-END (4)	H3, H4, H5	H6		
SAFETY	LEFT-TURN LEAVING (16)	B1, C2, C4, D1, I1, I2	A1, C1, C3, C5, D3	D6, H10	A2, A3, C7
SAFETY	MEDIAN COLLISIONS (15)	B1, C2, C4, G1	A1, B2, C3, C5, D3	C6, H10	A2, A3, C7, G3
SAFETY	MAINLINE HEAD-ON COLLISIONS (3)	H1, H2		H10	
DELAY	MINOR ROAD DELAY (17)	B1, D1, D2, E1	B2, C1, D4, D5, E2, F1, F2	D6, E3	A2, A3, C7, D7
DELAY	MEDIAN DELAY (15)	B1, C2, C4, E1	B2, C1, C3, C5, E2, F2	C6, E3	A2, A3, C7
DELAY	EXPRESSWAY DELAY (1)				A3

CONCERNS ADDRESSED VS TIME

		TIME		
	CONCERN ADDRESSED	SHORT	MEDIUM	LONG
SAFETY	ALL RIGHT-ANGLE (25)	B1, D1, D2, E1, E2, H1, H3, H4, H5, H7, H8, H9, I1, I2	A1, B2, C1, D6, E3, H6, H10	A2, A3, C7, D7
	FAR-SIDE RIGHT-ANGLE (10)	C2, C4, G1, G2	C3, C5, C6, D3, F2	G3
	NEAR-SIDE RIGHT-ANGLE (3)		D4, D5, F1	
	ALL REAR-END (8)	D2	A1, D5,F1, H10	A2, A3, C7
	MAINLINE REAR-END (14)	D1, E1, E2, H1, H7, H8, H9, I1, I2	C1, D3, D4, E3, F2	
	MINOR ROAD REAR-END (4)	H3, H4, H5	H6	
	LEFT-TURN LEAVING (16)	B1, C2, C4, D1, I1, I2	A1, C1, C3, C5, D3, D6, H10	A2, A3, C7
	MEDIAN COLLISIONS (15)	B1, C2, C4, G1	A1, B2, C3, C5, C6, D3, H10	A2, A3, C7, G3
	MAINLINE HEAD-ON COLLISIONS (3)	H1, H2	H10	
DELAY	MINOR ROAD DELAY (17)	B1, D1, D2, E1, E2	B2, C1, D4, D5, D6, E3, F1, F2	A2, A3, C7, D7
	MEDIAN DELAY (15)	B1, C2, C4, E1, E2	B2, C1, C3, C5, C6, E3, F2	A2, A3, C7
	EXPRESSWAY DELAY (1)			A3

CONCERNS ADDRESSED VS EFFECTIVENESS, COST, & TIME

	CONCERN ADDRESSED	BY	TREATMENTS			
SAFETY	ALL RIGHT-ANGLE (25)	EFFECTIVENESS	A2, A3, D6, H10, I2	A1, B1, B2, C1, C7, D1, D2, D7, H1, H3, H4, H5, H6, H7, H8, H9, I1		E1, E2, E3
		COST	B1, D1, D2, E1, H1, H3, H4, H5, H7, H8, H9, I1, I2	A1, B2, C1, E2, H6	D6, E3, H10	A2, A3, C7, D7
		TIME	B1, D1, D2, E1, E2, H1, H3, H4, H5, H7, H8, H9, I1, I2	A1, B2, C1, D6, E3, H6, H10		A2, A3, C7, D7
	FAR-SIDE RIGHT-ANGLE (10)	EFFECTIVENESS		C2, C3, C4, C5, C6, D3, F2, G1, G2, G3		
		COST	C2, C4, G1, G2	C3, C5, D3, F2	C6	G3
		TIME	C2, C4, G1, G2	C3, C5, C6, D3, F2		G3
	NEAR-SIDE RIGHT-ANGLE (3)	EFFECTIVENESS		D4, F1		D5
		COST		D4, D5, F1		
		TIME		D4, D5, F1		
	ALL REAR-END (8)	EFFECTIVENESS	A2, A3, H10	A1, C7, D2, F1		D5
		COST	D2	A1, D5, F1	H10	A2, A3, C7
		TIME	D2	A1, D5,F1, H10		A2, A3, C7
	MAINLINE REAR-END (14)	EFFECTIVENESS	I2	C1, D1, D3, D4, F2, H1, H7, H8, H9, I1		E1, E2, E3
		COST	D1, E1, H1, H7, H8, H9, I1, I2	C1, D3, D4, E2, F2	E3	
		TIME	D1, E1, E2, H1, H7, H8, H9, I1, I2	C1, D3, D4, E3, F2		
	MINOR ROAD REAR-END (4)	EFFECTIVENESS		H3, H4, H5, H6		
		COST	H3, H4, H5	H6		
		TIME	H3, H4, H5	H6		
	LEFT-TURN LEAVING (16)	EFFECTIVENESS	A2, A3, D6, H10, I2	A1, B1, C1, C2, C3, C4, C5, C7, D1, D3, I1		
		COST	B1, C2, C4, D1, I1, I2	A1, C1, C3, C5, D3	D6, H10	A2, A3, C7
		TIME	B1, C2, C4, D1, I1, I2	A1, C1, C3, C5, D3, D6, H10		A2, A3, C7
	MEDIAN COLLISIONS (15)	EFFECTIVENESS	A2, A3, H10	A1, B1, B2, C2, C3, C4, C5, C6, C7, D3, G1, G3		
		COST	B1, C2, C4, G1	A1, B2, C3, C5, D3	C6, H10	A2, A3, C7, G3
		TIME	B1, C2, C4, G1	A1, B2, C3, C5, C6, D3, H10		A2, A3, C7, G3
	MAINLINE HEAD-ON COLLISIONS (3)	EFFECTIVENESS	H10	H1		H2
		COST	H1, H2		H10	
		TIME	H1, H2	H10		
DELAY	MINOR ROAD DELAY (17)	EFFECTIVENESS	A2, A3, D6	B1, B2, C1, C7, D1, D2, D4, D7, F1, F2		D5, E1, E2, E3
		COST	B1, D1, D2, E1	B2, C1, D4, D5, E2, F1, F2	D6, E3	A2, A3, C7, D7
		TIME	B1, D1, D2, E1, E2	B2, C1, D4, D5, D6, E3, F1, F2		A2, A3, C7, D7
	MEDIAN DELAY (15)	EFFECTIVENESS	A2, A3	B1, B2, C1, C2, C3, C4, C5, C6, C7, F2		E1, E2, E3
		COST	B1, C2, C4, E1	B2, C1, C3, C5, E2, F2	C6, E3	A2, A3, C7
		TIME	B1, C2, C4, E1, E2	B2, C1, C3, C5, C6, E3, F2		A2, A3, C7
	EXPRESSWAY DELAY (1)	EFFECTIVENESS	A3			
		COST				A3
		TIME				A3

LEGEND				
EFFECTIVENESS	PROVEN	TRIED		EXPERIMENTAL
COST	LOW	MODERATE	HIGH	EXTREME
TIME	SHORT	MEDIUM		LONG

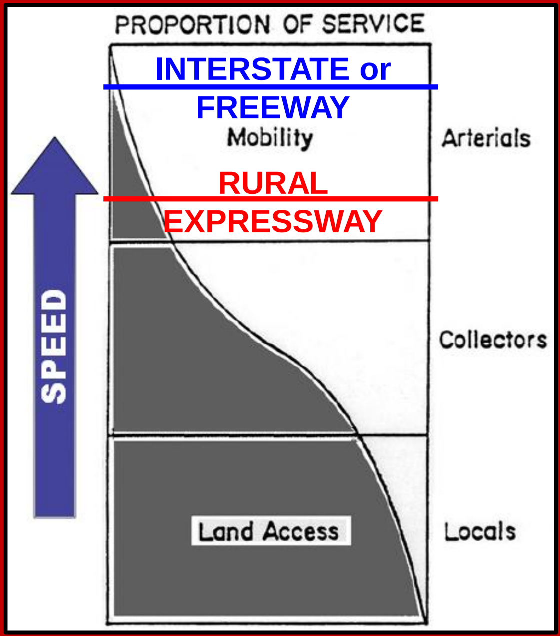
Category A: Improve Management of Access

The primary purpose of rural expressways is to provide mobility. Access is secondary, but necessary. This is a difficult balance to achieve. Managing and protecting the partial access control rights on rural expressways is a key factor in the safety of these facilities. The intent of the strategies presented in this category are to provide more stringent access control, thereby improving the safety of existing access points and preserving the high-speed mobility of rural expressway corridors.

A1: Close Low Volume Intersections & Connect via Frontage Roads

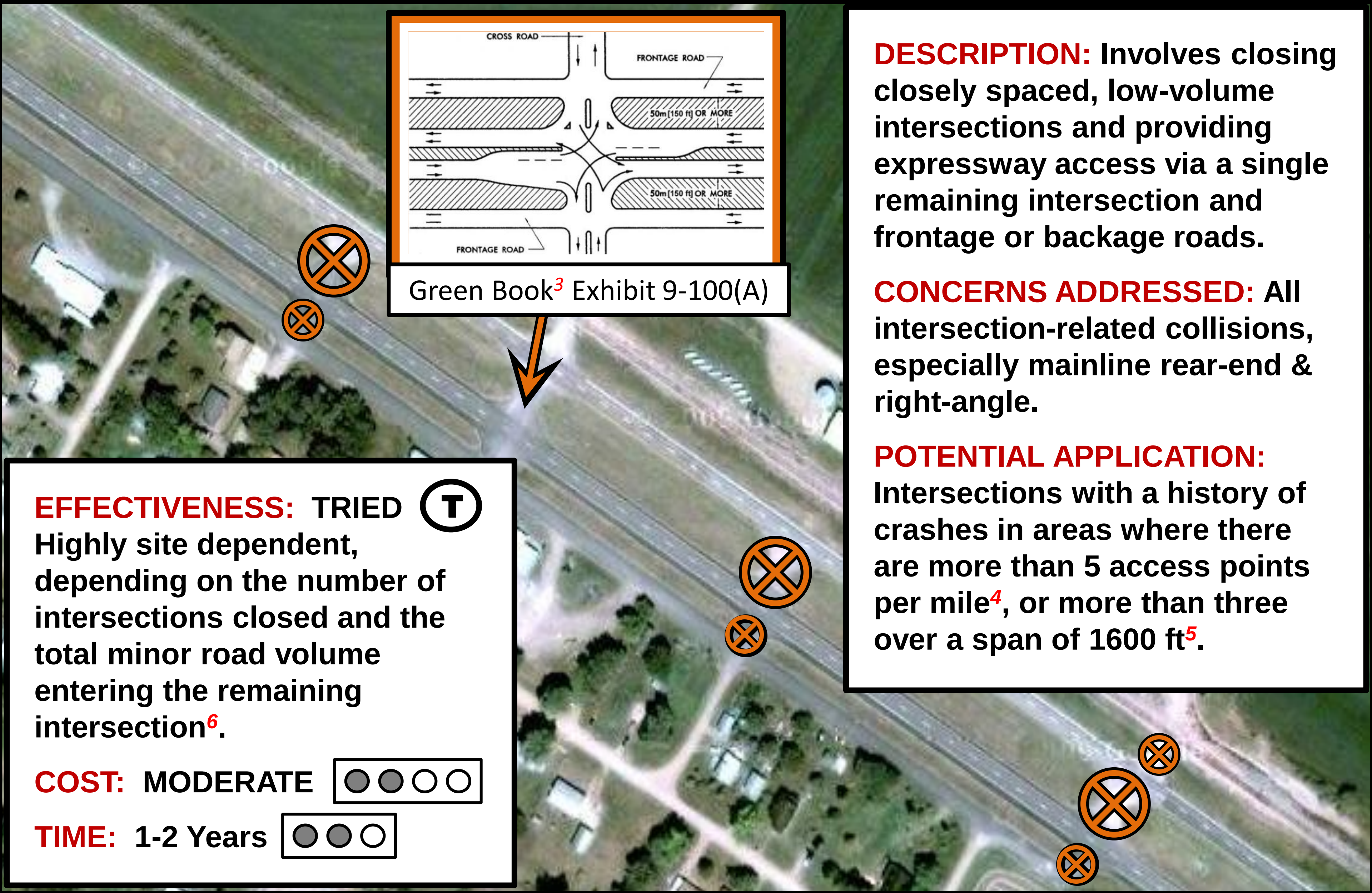
A2: Convert Single At-Grade Intersection to Interchange

A3: Convert Expressway Corridor to Freeway



Green Book[3] Exhibit 1-5

A1: Close Low Volume Intersections and Connect via Frontage Roads



Green Book[3] Exhibit 9-100(A)

DESCRIPTION: Involves closing closely spaced, low-volume intersections and providing expressway access via a single remaining intersection and frontage or backage roads.

CONCERNS ADDRESSED: All intersection-related collisions, especially mainline rear-end & right-angle.

POTENTIAL APPLICATION: Intersections with a history of crashes in areas where there are more than 5 access points per mile[4], or more than three over a span of 1600 ft[5].

EFFECTIVENESS: TRIED (T)
Highly site dependent, depending on the number of intersections closed and the total minor road volume entering the remaining intersection[6].

COST: MODERATE ●●○○

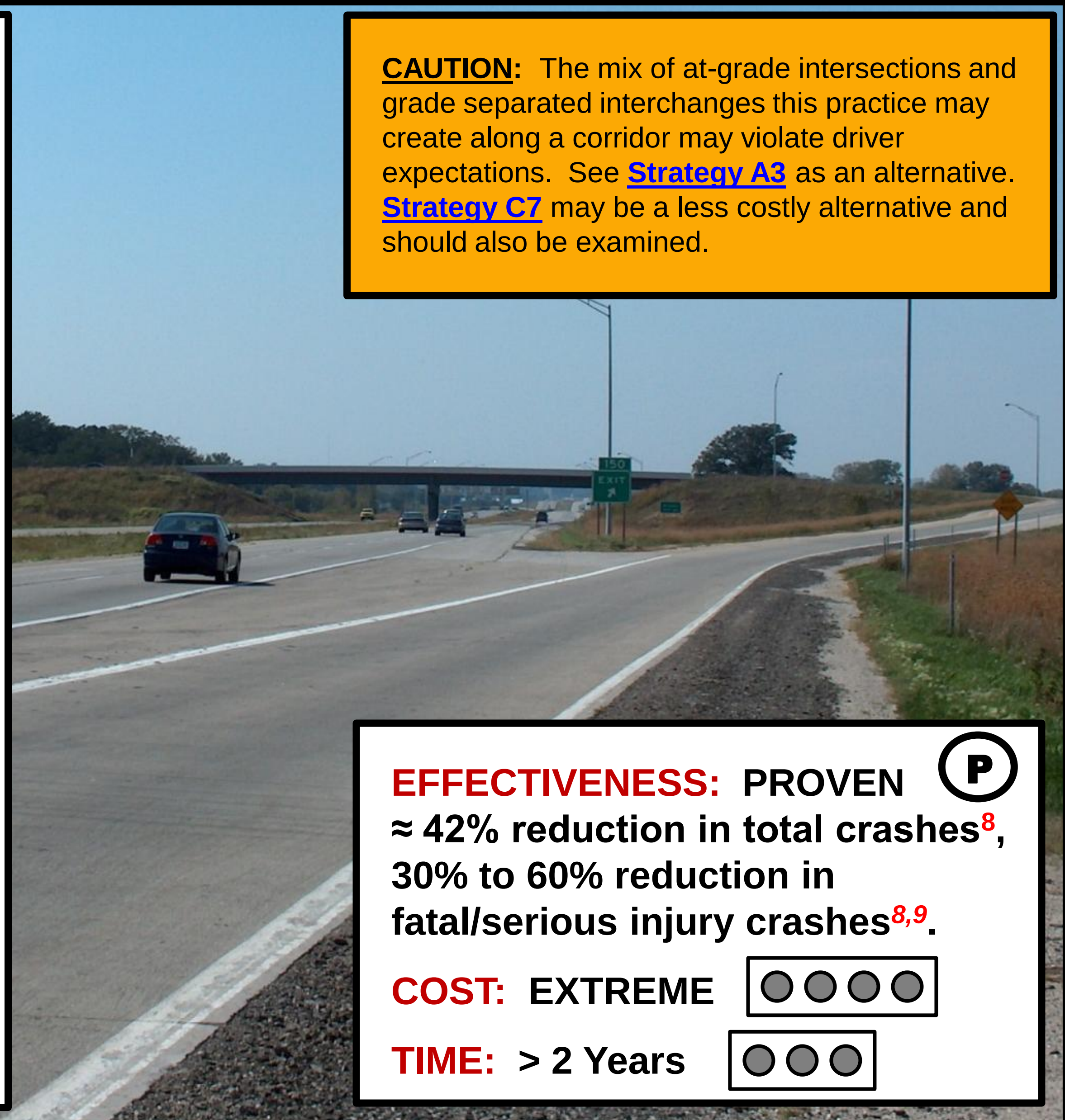
TIME: 1-2 Years ●●○

A2: Convert Single At-Grade Intersection to Interchange

DESCRIPTION: **Involves converting a single at-grade intersection to a grade-separated interchange. May also involve closing other nearby expressway intersections to force more traffic through the interchange.**

CONCERNS ADDRESSED: **All intersection-related crashes (particularly severe right-angle) and delay on minor roadway approaches.**

POTENTIAL APPLICATION: **High volume expressway intersections (with total minor roadway entering volumes around 2,000 vpd) with a history of severe crashes[7]. In addition, Chapter 10 of the AASHTO Green Book[3] describes six general interchange warrants.**



CAUTION: The mix of at-grade intersections and grade separated interchanges this practice may create along a corridor may violate driver expectations. See **Strategy A3** as an alternative. **Strategy C7** may be a less costly alternative and should also be examined.

EFFECTIVENESS: **PROVEN** **P**
≈ 42% reduction in total crashes[8], 30% to 60% reduction in fatal/serious injury crashes[8,9].

COST: **EXTREME** ●●●●

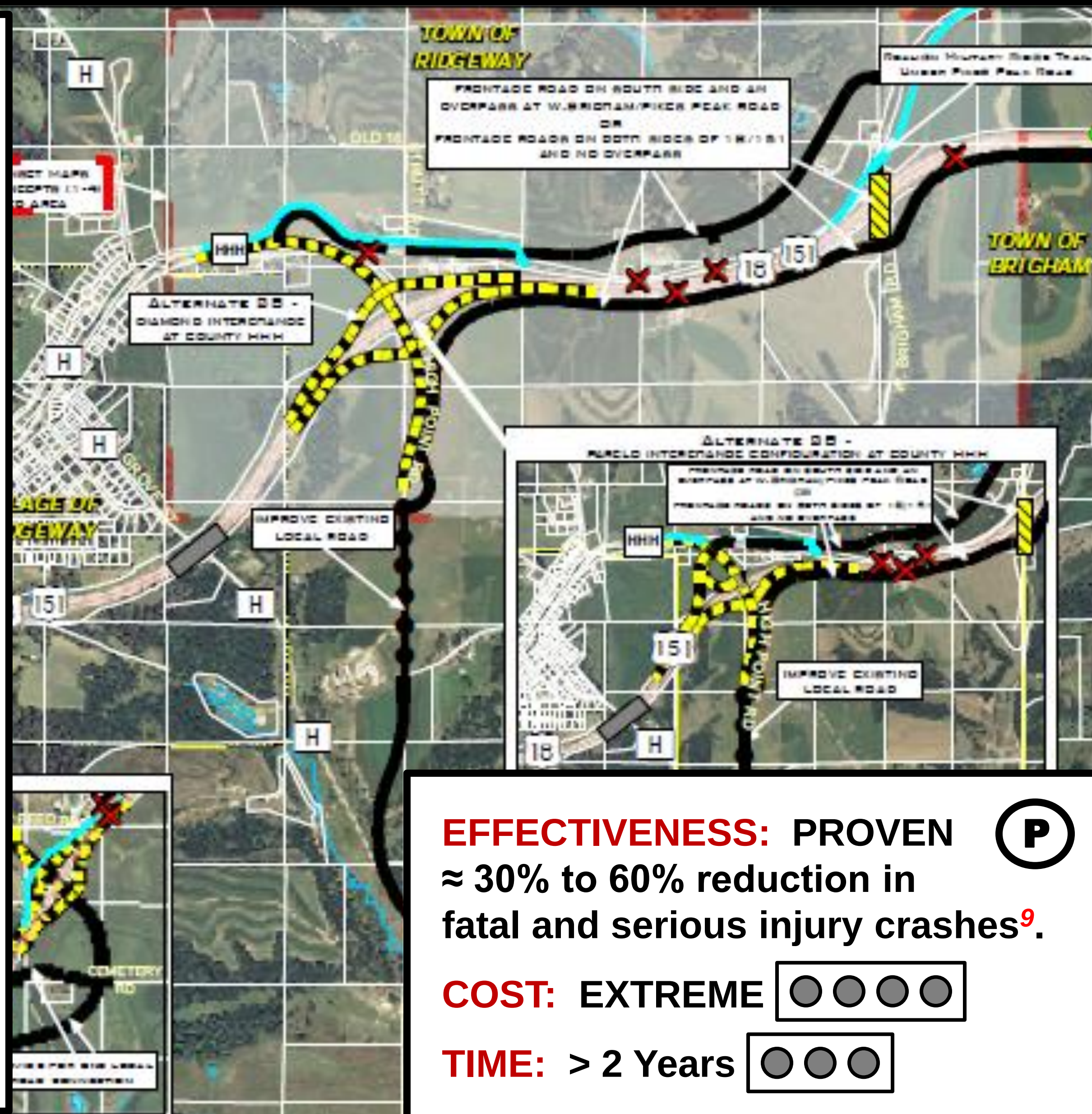
TIME: **> 2 Years** ●●●

A3: Convert Expressway Corridor to Freeway

DESCRIPTION: Involves upgrading an expressway corridor to full access control by eliminating all at-grade access points and constructing grade separations/interchanges at key locations.

CONCERNS ADDRESSED: All intersection-related crashes (especially severe right-angle) and delay on both mainline and minor roadways.

POTENTIAL APPLICATION: Corridors with mainline traffic volumes approaching 10,000 vpd or a history of severe crashes at intersections[10]. May be most appropriate for urban fringe and bypass corridors.



EFFECTIVENESS: PROVEN (P)
≈ 30% to 60% reduction in fatal and serious injury crashes[9].

COST: EXTREME ●●●●

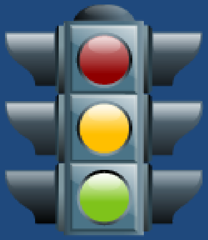
TIME: > 2 Years ●●●

Category B: Choose Appropriate Intersection Traffic Control

The type of traffic control chosen for an intersection has a strong influence on the frequency, severity, and type of crashes that occur at an intersection. The strategies within this category focus strictly on selecting the appropriate traffic control for rural expressway intersections and do not include strategies which alter intersection geometrics.

B1: Convert Intersection to All-Way Stop-Control

B2: Provide Signalization



B1: Convert Intersection to All-Way Stop Control

DESCRIPTION: **Involves converting a two-way stop-controlled expressway intersection (base traffic control condition) to an all-way stop-control condition.**

CONCERNS ADDRESSED: **High frequency of severe right-angle crashes and excessive minor road delays.**

POTENTIAL APPLICATION: **Intersections with history of right-angle and turning crashes, moderate/relatively balanced traffic volumes on all approaches[2], and a relatively narrow median width.**

CAUTION: Potential drawbacks to this treatment include expressway driver expectancy violation, reduced expressway mobility (delays), & trade-off with right-angle to rear-end crashes.

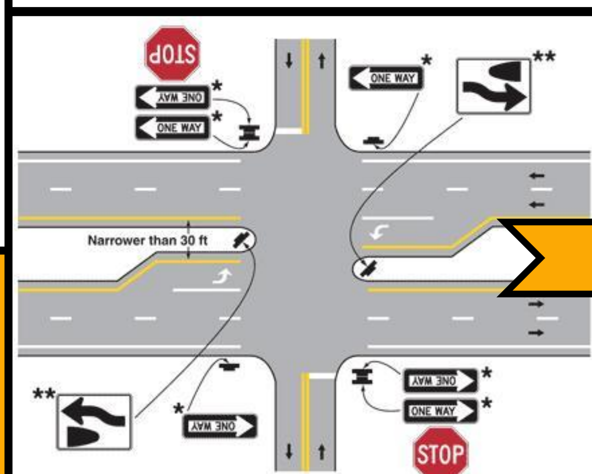
EFFECTIVENESS: **TRIED**

≈ 47-64% reduction in total intersection crashes[8,12,13].

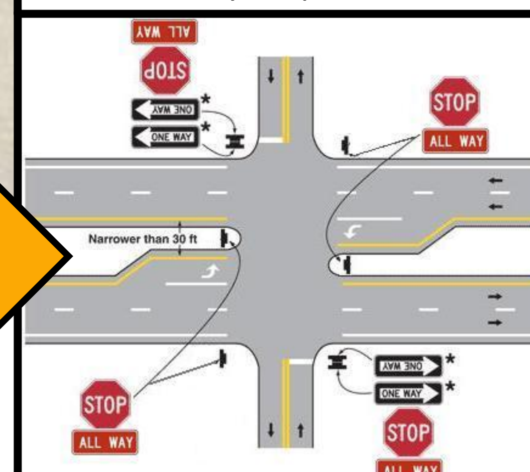
COST: **LOW** ●○○○

TIME: **< 1 Year** ●○○

Standard Control
MUTCD[11] Figure 2B-16



All-Way Stop Control

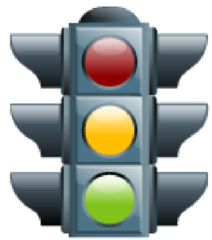


B2: Provide Signalization

DESCRIPTION: Involves installing traffic signals at a previously unsignalized intersection.

CONCERNS ADDRESSED: High frequency of severe right-angle crashes with excessive minor road delays.

POTENTIAL APPLICATION: Medium to high-volume unsignalized intersections where all other less restrictive forms of traffic control have been considered. Preferably, the median width would be less than 60 feet[3]. Larger median widths would require separate signals for each roadway of the divided highway.



EFFECTIVENESS: TRIED

T

Traffic signals generally increase crash rates, but reduce severity as a result of trading off right-angle for rear-end collisions (≈ 77% right-angle reduction and ≈ 58% increase in rear-end)[8]. However, great variability in their safety effects have been observed[14].

COST: MODERATE ●●○○

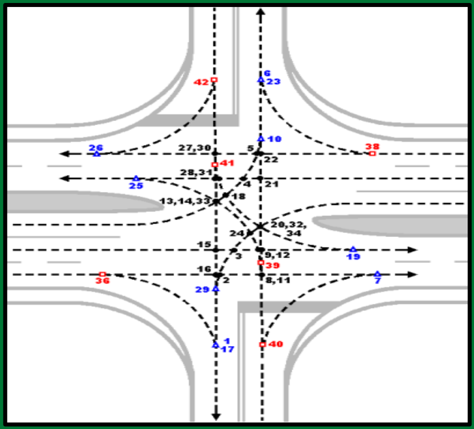
TIME: 1-2 Years ●●○

CAUTION: Avoid installing signal control on rural expressways whenever possible[2,3]. Signals reduce expressway mobility, violate expressway driver expectancy, & increase the potential for severe rear-end crashes and red-light running. As a result, some highway agencies prohibit the installation of traffic signals on rural expressways due to the delays caused to through expressway traffic[2,7].

Category C: Reduce Conflict Points Through Geometric Design Improvements

Decreasing the number of conflict points at an intersection can reduce the frequency and severity of intersection crashes. The strategies within this category focus strictly on geometric improvements which reduce or relocate intersection conflict points and/or change the type of vehicle-vehicle conflicts that can occur at a typical rural expressway intersection. Treatments C2 through C6 are good applications for high growth corridors as they lend themselves to two-phase signal operation if traffic signals are needed in the future. As such, placement of median openings & U-turns should consider future signal coordination.

- **C1: Provide or Lengthen Expressway Left/Right-Turn Lanes**
- **C2: Close Median Crossovers (Right-In, Right-Out Access Only)**
- **C3: Convert to U-Turn Intersection**
- **C4: Provide Directional Median Opening**
- **C5: Convert to J-Turn Intersection (JTI)**
- **C6: Convert to Offset T-Intersection**
- **C7: Convert to One-Quadrant Interchange**



C1: Provide or Lengthen Expressway Left/Right-Turn Deceleration Lanes

DESCRIPTION: Involves installing or lengthening expressway turn lanes at unsignalized intersections.

CONCERNS ADDRESSED: High frequency of mainline rear-end & sideswipe/weaving crashes resulting from the conflict between turning and following vehicles[2]. Also right-angle & left-turn leaving collisions by enabling drivers to determine destinations of oncoming expressway traffic earlier, giving them more time to make improved gap selection decisions.

POTENTIAL APPLICATION: Unsignalized intersections with moderate to high turn volumes, a history of mainline rear-end & sideswipe crashes, and no turn lanes or existing turn lanes that are not long enough for deceleration and storage of all turning vehicles[2].

EFFECTIVENESS: TRIED

T

Depends on existing turn lane length, approach speeds & volumes, turning volumes, and available stopping sight distance[2]. Overall crash reduction ≈ 14% for providing a single right-turn lane[8], ≈ 28% for a left-turn lane[8], and ≈ 7% for extending a deceleration lane by 100 feet[8].

COST: MODERATE

TIME: 1-2 Years

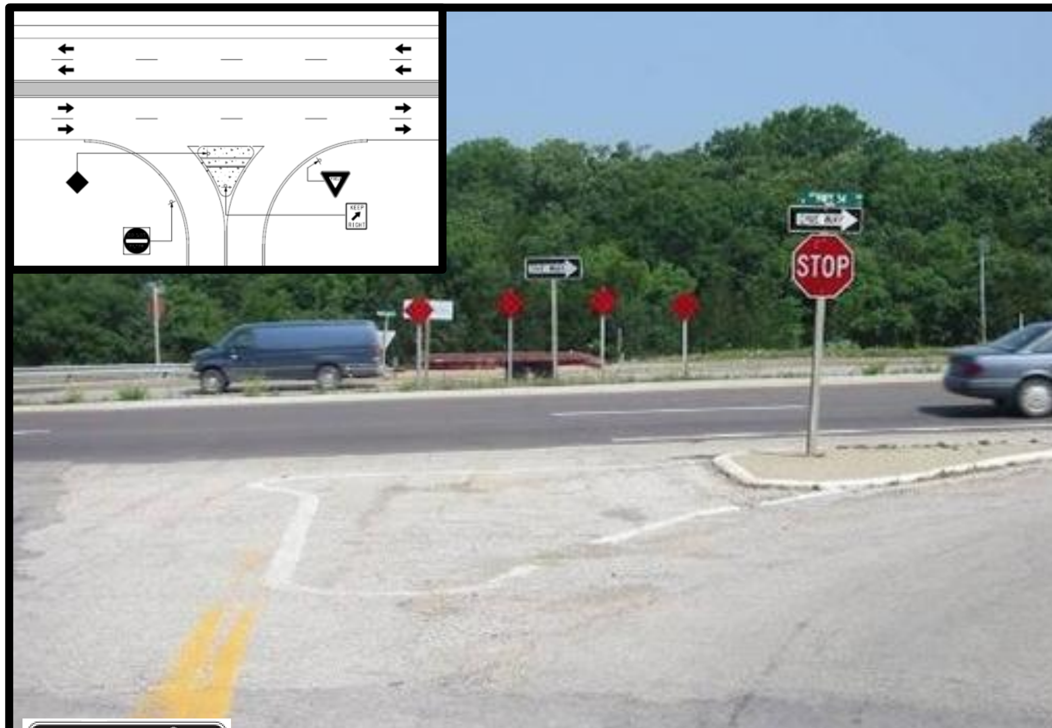
CAUTION: Appropriate turn lane lengths should be based on policies of individual highway agencies. The use of offset turn lanes is preferred (See Strategies D3 & D4).

C2: Close Median Crossovers (Right-In, Right-Out Access Only)

DESCRIPTION: **Involves closing the median leaving right-in right-out access only, while ensuring alternate indirect routes are still available.**

CONCERNS ADDRESSED: **Far-side right-angle & all left-turn related collisions.**

POTENTIAL APPLICATION: **Unsignalized intersections with a history of severe left-turn or far-side right-angle crashes and relatively low volumes of crossing/left-turn movements from the minor road and relatively low left-turn volumes from the expressway.**



EFFECTIVENESS: **TRIED** **T**

Elimination of nearly all left-turn and far-side right-angle crashes at the treated intersection[2], while crash migration may occur.

COST: **LOW** ●○○○

TIME: **<1 Year** ●○○

CAUTION: This treatment may change the nature of access along a corridor & should be used where indirect turn opportunities are available. If the indirect movements have moderate to high volume, other alternatives should be considered (see Strategies C3, C4, & C5).

C3: Convert to U-Turn Intersection

DESCRIPTION: Involves closing the median leaving right-in right-out access only, while providing alternate indirect access via median U-turns. Reduces total intersection conflict points from 42 to 16.

CONCERNS ADDRESSED: Far-side right-angle & all left-turn related collisions.

POTENTIAL APPLICATION: Unsignalized intersections with a history of severe left-turn or far-side right-angle crashes and moderate volumes of crossing/left-turn movements from the minor road and relatively low left-turn volumes from the expressway.

EFFECTIVENESS: TRIED

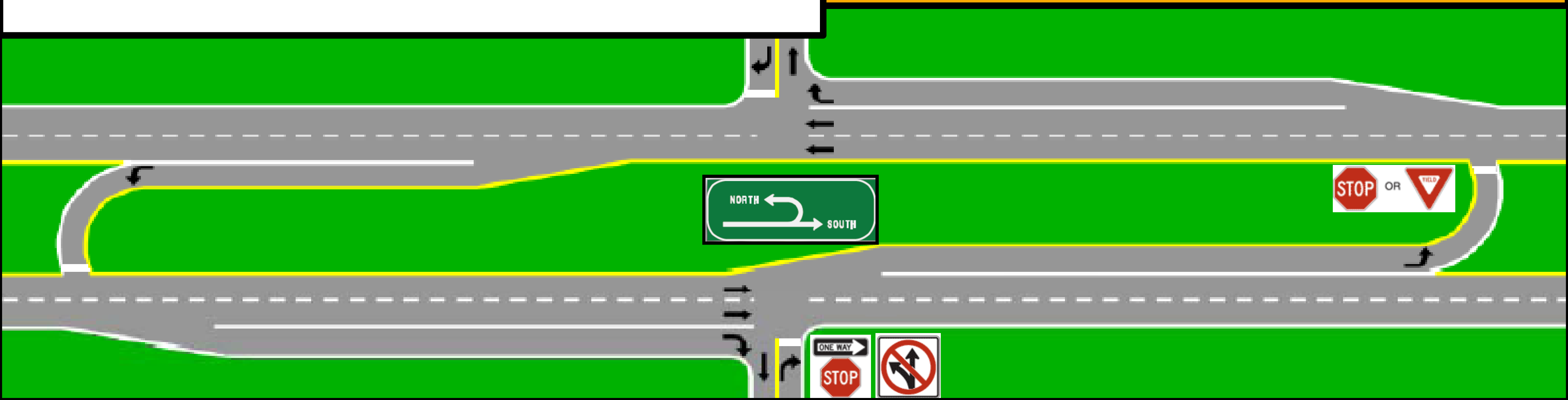
T

Elimination of nearly all left-turn and far-side right-angle crashes at the treated intersection[2].

COST: MODERATE ●●○○

TIME: 1-2 Years ●●○

CAUTION: U-turn spacing & addition of accel/decel lanes & U-turn loons should be carefully considered. If left-turn volumes from the expressway are moderate to high, Strategy C5 should be considered. Advantages over Strategy C5 include the ability to locate U-turns closer to the main intersection & extend left/right-turn deceleration lanes all the way from the main intersection to the U-turns.



C4: Provide Directional Median Opening

DESCRIPTION: **Involves restricting direct left-turn and crossing maneuvers from the minor roads by providing a channelized median with offset left-turn lanes ([Strategy D3]) for the exclusive use of left-turning traffic leaving the expressway.**

CONCERNS ADDRESSED: **Far-side right-angle and left-turn leaving collisions.**

POTENTIAL APPLICATION: **Unsignalized intersections with a history of severe far-side right-angle crashes and relatively low volumes of crossing/left-turn movements from the minor road with relatively high left-turn volumes from the expressway.**

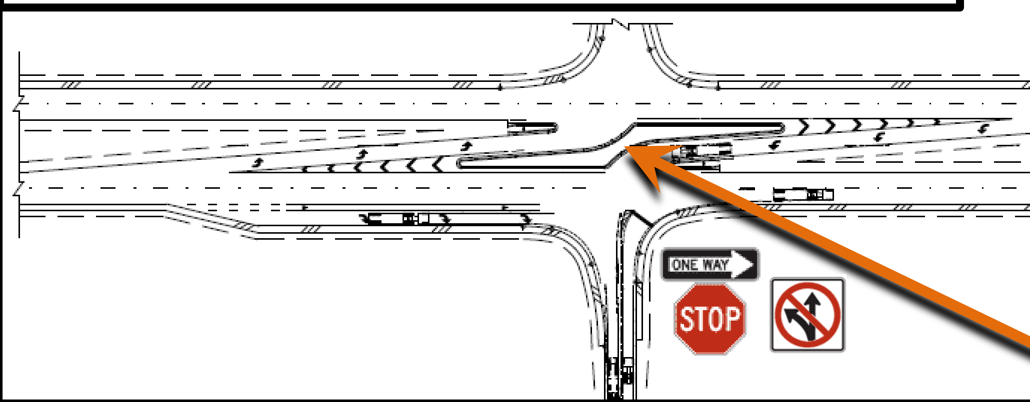
EFFECTIVENESS: **TRIED**

Elimination of nearly all far-side crashes at the treated intersection[2]. Approximately 15% reduction in overall crashes has been observed in urban areas[15]; however, crash migration may occur.

COST: **LOW** ●○○○

TIME: **<1 Year** ●○○

CAUTION: This treatment may change the nature of access along a corridor & should be used where indirect turn opportunities are available for minor road traffic. If the minor road indirect movements have a moderate to high volume, [Strategy C5] should be considered instead.



C5: Convert to J-Turn Intersection (JTI)

DESCRIPTION: Involves restricting direct left-turn & crossing maneuvers from the minor roads by providing a directional median opening (Strategy C4) combined with U-turns to accommodate indirect minor road movements. Reduces total intersection conflict points from 42 to 24.

CONCERNS ADDRESSED: Far-side right-angle & left-turn leaving crashes.

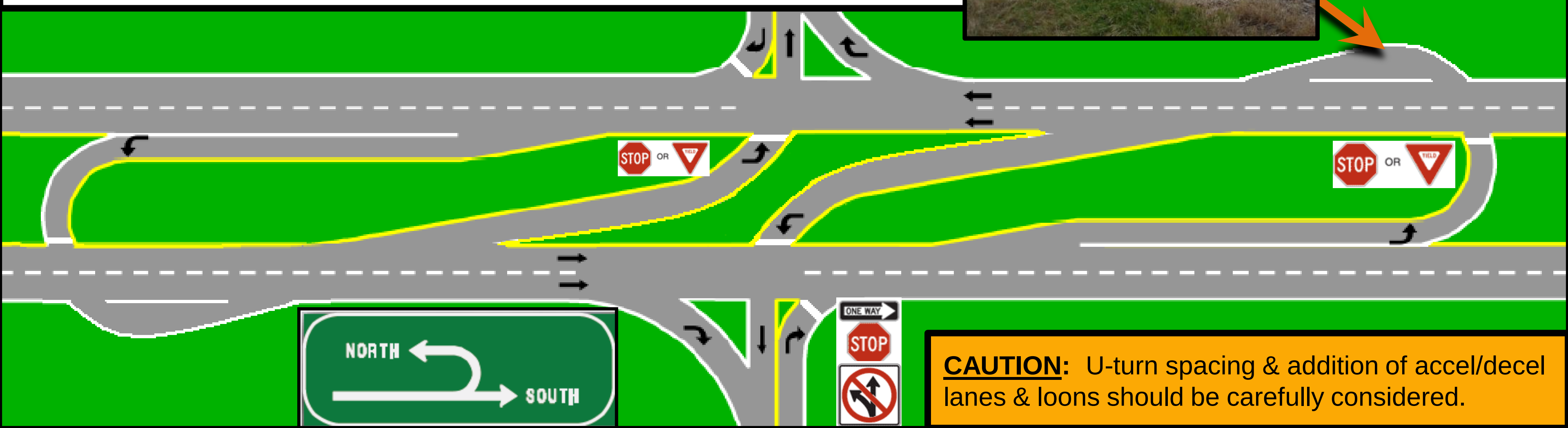
POTENTIAL APPLICATION: Unsignalized intersections with a history of severe far-side right-angle crashes & moderate volumes of crossing/left-turn traffic on the minor roads with relatively high left-turn volumes from the expressway.

EFFECTIVENESS: TRIED (T)
Elimination of nearly 100% far-side right-angle crashes & ≈ 43-92% reduction in total intersection crashes[16,17].

COST: MODERATE ●●○○

TIME: 1-2 Years ●●○

Loon or bulb-out for U-turn



CAUTION: U-turn spacing & addition of accel/decel lanes & loons should be carefully considered.

C6: Convert to Offset T-Intersection

DESCRIPTION: **Involves closing one minor road approach at a 4-legged intersection and moving it either up or downstream to create two independent 3-legged T-intersections. A right-left (R-L) configuration is preferred. Reduces total conflict points from 42 to 26. Conflict points at a R-L can be further reduced by making the minor roads right-out only with lefts & U-turns allowed from the major road.**

CONCERNS ADDRESSED: **Far-side right-angle collisions by creating indirect crossing maneuvers.**

POTENTIAL APPLICATION: **Two-way stop-controlled intersections with a history of far-side right-angle crashes and relatively low through and left-turn volumes on the minor road or where the median is too narrow to store the design crossing minor road vehicle[16].**

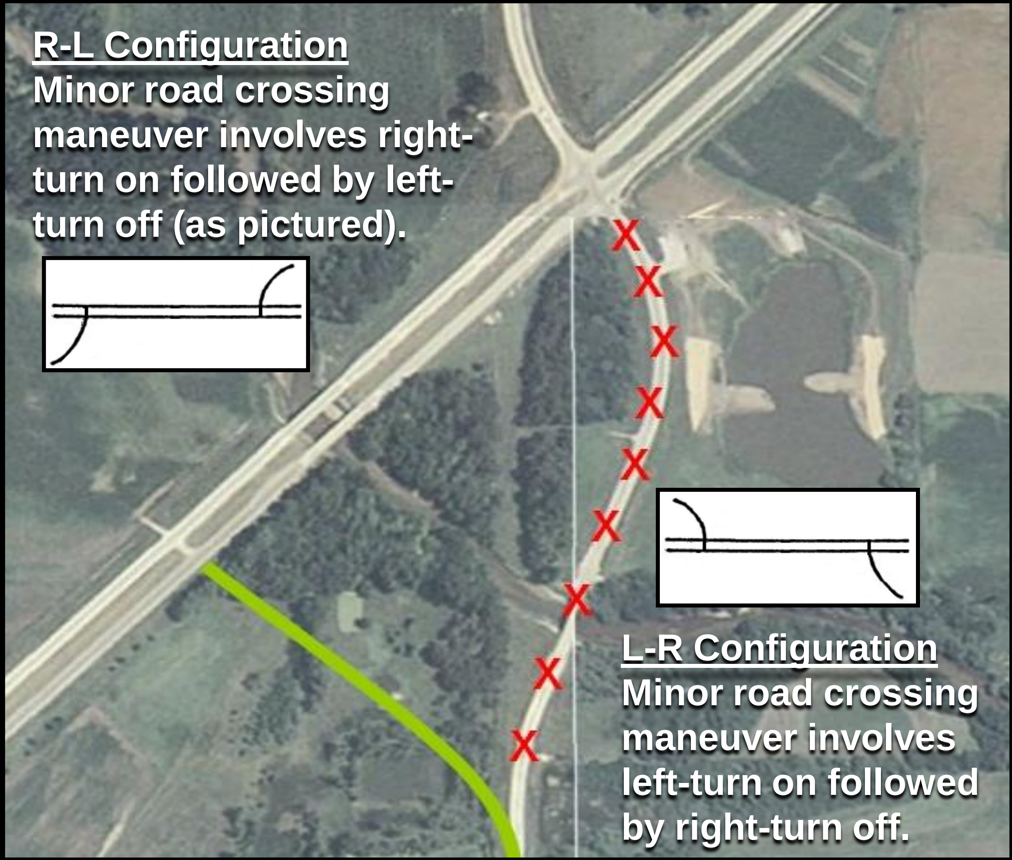
CAUTION: Minimum spacing between T-intersections should be carefully considered as well as the volumes of commercial vehicles and farm equipment making the indirect crossing maneuvers.

EFFECTIVENESS: **TRIED** (T)

≈ 40% to 60% reduction in total crashes[2,16,18].

COST: **HIGH** ●●●○

TIME: **1-2 Years** ●●○



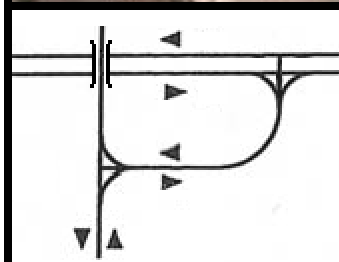
C7: Convert to One-Quadrant Interchange

DESCRIPTION: Involves replacing an existing four-legged at-grade intersection with a combination of a three-legged intersection (on the expressway) and a grade separation to accommodate through traffic on the minor road. All turning movements are completed via a two-way connector road joining the intersecting roadways. Conflict points are reduced from 42 to 11 along the expressway.

CONCERNS ADDRESSED: Right-angle, left-turn leaving, & median collisions.

POTENTIAL APPLICATION: Unsignalized intersections with a history of severe right-angle crashes and heavy through volumes on the minor road. The location of the connector road depends on traffic flow and availability of right-of-way.

CAUTION: This alternative will change some simple right-turns into left-turns and add out of distance travel. Other less costly alternatives should be considered first.



Green Book[3] Exhibit 10-1C

EFFECTIVENESS: TRIED

≈ 60% reduction in crash severity[16].

COST: EXTREME

TIME: > 2 Years

Category D: Improve Intersection Sight Distance

Limited sight distance for drivers approaching or stopped at an intersection can lead to collisions at unsignalized intersections. Sight obstructions may be caused by roadside objects (buildings, trees, crops, signs, sign posts, etc.), the roadway itself (vertical/horizontal alignment), and vehicles on the roadway. The strategies within this category are intended to provide clear or improved sight-lines for drivers approaching or stopped at rural expressway intersections so that they may better recognize the presence of other traffic using the intersection.

D1: Provide Clear Sight Triangles from Stop-Controlled Approaches & the Median

D2: Move Minor Road/Median Stop/Yield Bars Closer to Expressway &/or Provide Dotted Edge Line Extensions

D3: Provide Offset Left-Turn Lanes

D4: Provide Offset Right-Turn Lanes

D5: Redesign Minor Road Right-Turn Channelization

D6: Realign Intersection Approaches to Reduce or Eliminate Skew

D7: Modify Horizontal/Vertical Alignment of Expressway Approaches

D1: Provide Clear Sight Triangles from Stop-Controlled Approaches & the Median

DESCRIPTION: Involves improving intersection sight distance (ISD) by removing roadside or median obstructions (natural & artificial) within departure sight triangles. ISD guidelines are established by AASHTO[3].

CONCERNS ADDRESSED: Patterns of crashes related to lack of ISD (particularly right-angle collisions).

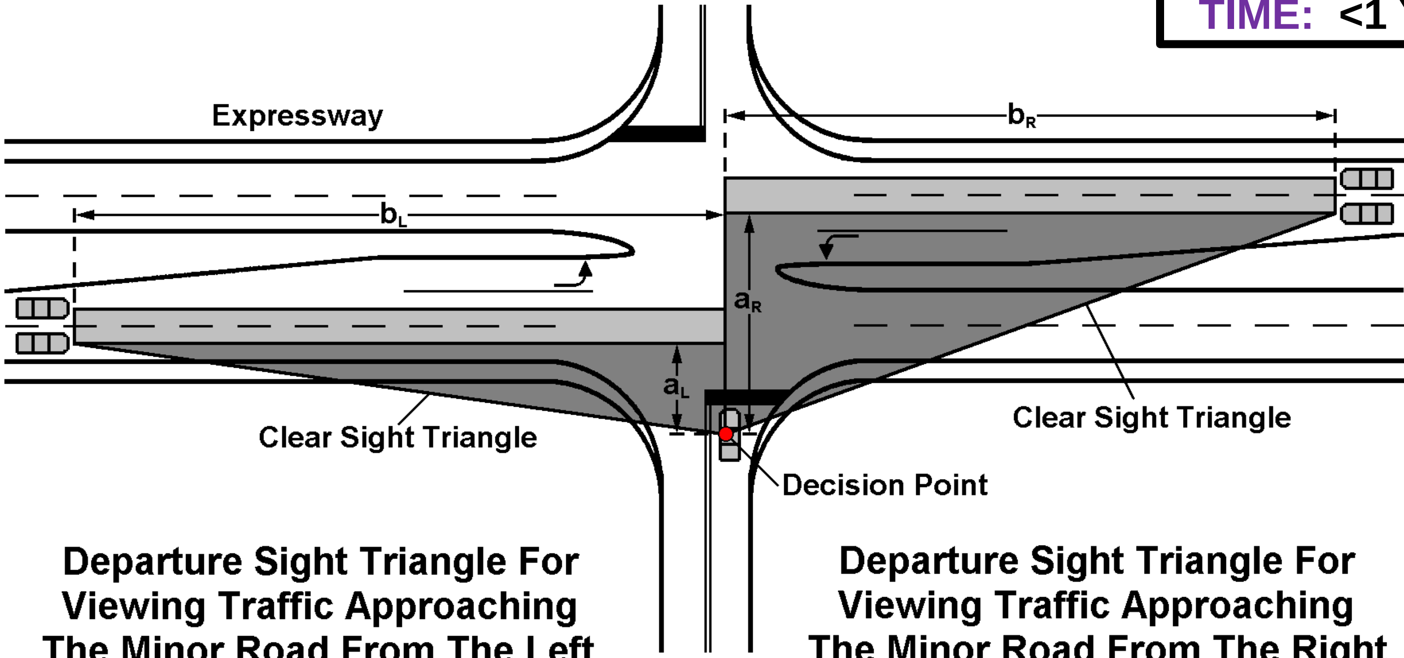
POTENTIAL APPLICATION: Unsignalized intersections with restricted sight distance due to roadside or median obstructions.

EFFECTIVENESS: TRIED (T)

Up to a 20% reduction in crashes related to lack of sight distance and ≈ 48% reduction in injury crashes, depending on the severity of the sight restriction and the number of intersection quadrants affected[2,8].

COST: LOW ●○○○

TIME: <1 Year ●○○



Departure Sight Triangle For Viewing Traffic Approaching The Minor Road From The Left

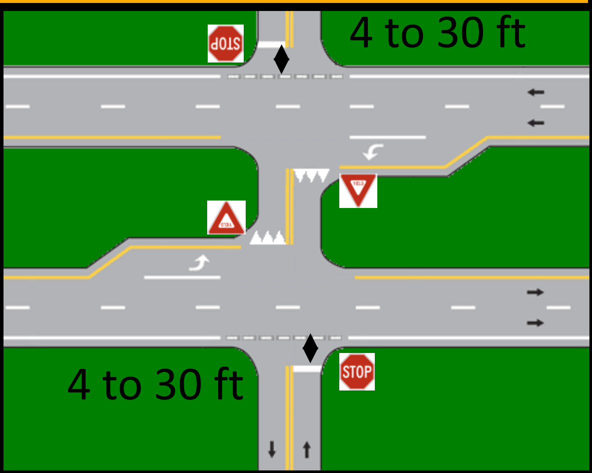
Departure Sight Triangle For Viewing Traffic Approaching The Minor Road From The Right

NOTE: This strategy may include using thinner sign posts, modifying sign height, or paving medians (to prevent vegetation growth) near intersections.

D2: Move Minor Road/Median Stop/Yield Bars Closer to Expressway &/or Provide Dotted Edge Line Extensions

DESCRIPTION: Involves moving minor road stop bars &/or median yield/stop bars as close to the expressway through lanes as possible (≥ 4 ft) to encourage drivers to stop at a location that would maximize their ISD. See MUTCD[11] Section 3B.16 for stop & yield line placement guidelines. May also include extending expressway edge/center lines through an intersection to more clearly delineate the expressway through lanes.

NOTE: May combine with Strategy H6. See Strategy G1 for more on median delineation.



CONCERNS ADDRESSED: Crashes (particularly right-angle & rear-end) related to lack of ISD or lack of driver recognition of the intersection or of the stop/yield control.

POTENTIAL APPLICATION: Unsignalized intersections where ISD can be improved by moving the stop/yield bars forward or where intersection recognition seems to be an issue.

EFFECTIVENESS: TRIED (T)

Crash rates decrease as the total distance across an expressway intersection decreases[19].

COST: LOW ●○○○

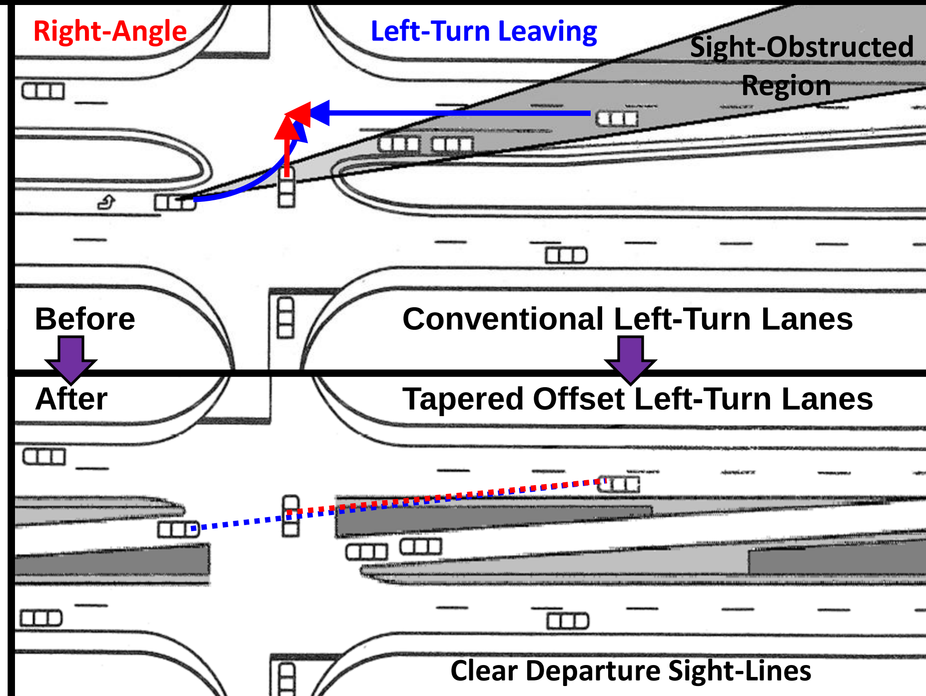
TIME: <1 Year ●○○

D3: Provide Offset Left-Turn Lanes

DESCRIPTION: Involves moving left-turn deceleration lanes further into the median so opposing left-turn vehicles do not obstruct each other's sight line toward oncoming through traffic (i.e., a positive offset[20]). Parallel or tapered designs may be used[3].

CONCERNS ADDRESSED: Left-turn leaving, mainline rear-end, & far-side right-angle crashes resulting from sight-line obstructions due to left-turn vehicles in conventional left-turn lanes. Also addresses median locking by providing a separate holding point for left-turn traffic.

POTENTIAL APPLICATION: Intersections where left-turn leaving mainline volumes are at least 60 vph in both directions[21], there are large volumes of left-turn leaving trucks, or where patterns of left-turn leaving, mainline rear-end, or far-side right-angle collisions exist as a result of shadowing. The median must be wide enough (≥ 24 ft)[22] to provide the appropriate offset.



CAUTION: Signage & marking are important to limit driver confusion regarding vehicle placement & priority (see Strategy H2). Follow your agency's design guide. Future signalization should be considered in the design; however, indirect left-turn alternatives should be considered first in high-growth areas.

EFFECTIVENESS: TRIED

T

≈ 85-100% reduction in left-turn leaving crashes, 33-50% crash reduction overall[8,16].

COST: MODERATE ●●○○

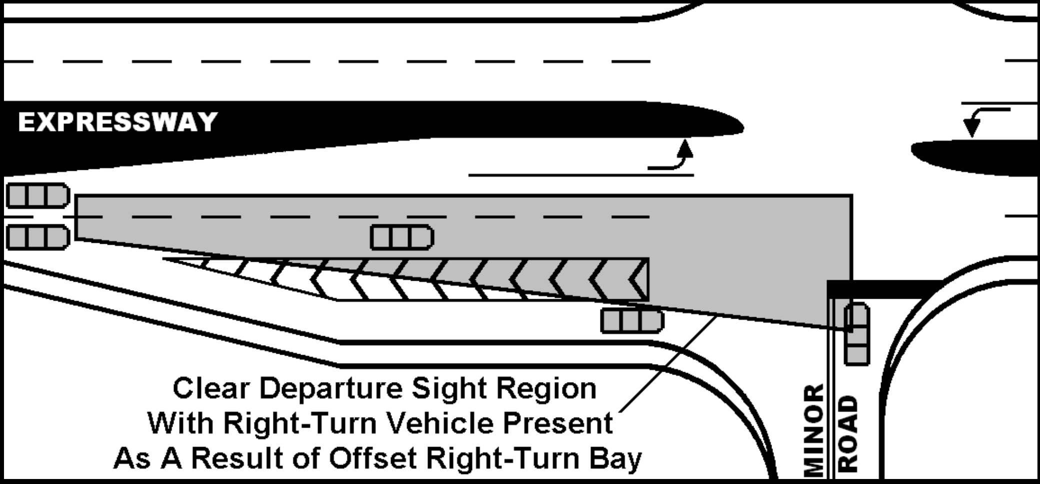
TIME: 1-2 Years ●●○

D4: Provide Offset Right-Turn Lanes

DESCRIPTION: **Involves moving right-turn deceleration lanes laterally to the right (offset) as far as necessary so that right-turning vehicles do not obstruct the sight line of minor road drivers positioned at the adjacent stop bar. Parallel and tapered designs have been used**[16]**.**

CONCERNS ADDRESSED: **Near-side right-angle or mainline rear-end collisions resulting from sight-line obstructions (shadowing) due to the presence of right-turning vehicles.**

POTENTIAL APPLICATION:
Unsignalized expressway intersections with patterns of near-side right-angle collisions, right-turn volumes that warrant a right-turn deceleration lane (>30 vph)[23]**, large volumes of right-turn trucks, or other potential sight line difficulties (horizontal/vertical curves, intersection skew, etc.).**



EFFECTIVENESS: **TRIED** (T)
≈ 50% reduction in near-side right-angle crashes[16]**.**

COST: **MODERATE** ●●○○

TIME: **1-2 Years** ●●○

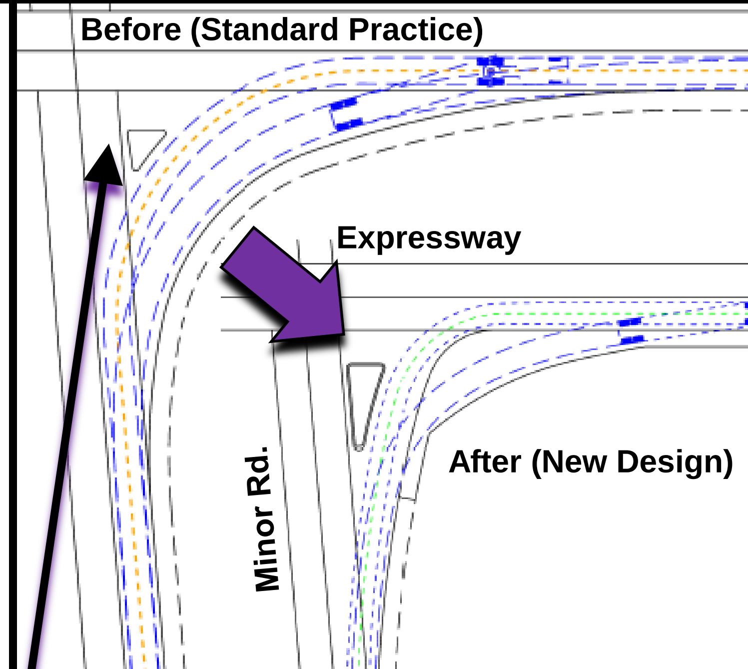
CAUTION: Ensure the offset turn lane does not appear to be an exit ramp[16]. May be used with Strategies D2, D5, & H6.

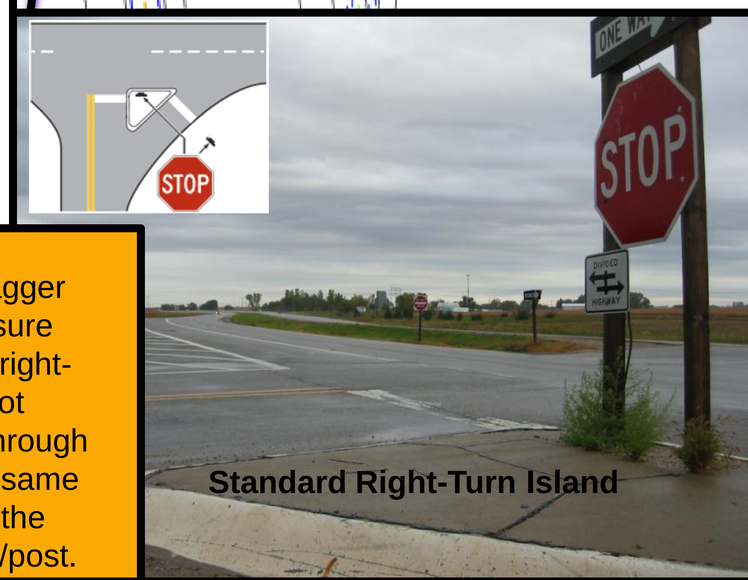
D5: Redesign Minor Road Right-Turn Channelization

DESCRIPTION: Involves reconstructing the right-turn channelization island along the minor road to provide an improved observation angle for minor road right-turn drivers so they don't have to turn their heads as much to view oncoming traffic. Includes the use of edge line rumble stripes to help control the angle of right-turn vehicles. The edge of pavement is determined from the path of a PC with truck off-tracking accommodated via a paved shoulder apron.

CONCERNS ADDRESSED: Near-side right-angle and mainline rear-end collisions. May also reduce rear-end collisions along the minor road.

POTENTIAL APPLICATION: Expressway intersections with a pattern of near-side right-angle right-turn merge/rear-end collisions & standard or no right-turn channelization on the minor road(s).





Standard Right-Turn Island

EFFECTIVENESS: EXPERIMENTAL (E)

COST: MODERATE ●●○○

TIME: 1-2 Years ●●○

CAUTION: Stagger stop bars to ensure line-of-sight for right-turn drivers is not obstructed by through vehicles on the same approach or by the island stop sign/post.

D6: Realign Intersection Approaches to Reduce or Eliminate Skew

DESCRIPTION: **Involves realignment of minor road approaches from a skewed intersection angle to a right angle or closer to it in order to provide improved observation angles for minor road drivers so they don't have to turn their heads as much to view oncoming traffic.**

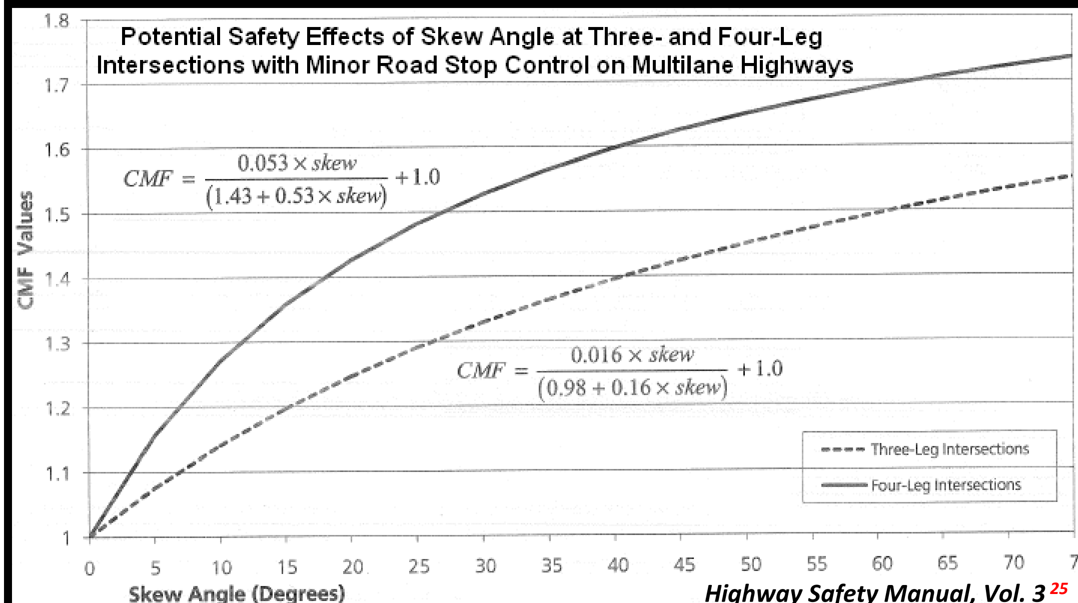
CONCERNS ADDRESSED: **Patterns of crashes (especially right-angle) related to insufficient sight distance or awkward sight lines. May be particularly beneficial to older drivers.**

POTENTIAL APPLICATION:
Unsignalized skewed intersections with a high frequency of crashes resulting from insufficient intersection sight distance and awkward sight lines.

EFFECTIVENESS: **PROVEN** **P**

Reduction in total crashes is dependent on the reduction in the intersection skew angle[2]. Crash severity is also reduced with less skew[24,25].

COST: **HIGH** ●●●○ **TIME:** **1-2 Years** ●●○



CAUTION: Avoid creating sharp horizontal curvature when realigning a skewed approach[2]. Strategy C6 may be a preferred alternative.

D7: Modify Horizontal/Vertical Alignment of Expressway Approaches

DESCRIPTION: Involves modification of expressway alignment (vertical or horizontal) near at-grade intersections.

CONCERNS ADDRESSED: Patterns of crashes (especially right-angle) related to lack of adequate intersection sight distance due to horizontal curvature, vertical curvature, or independent vertical alignments of the two one-way roadways.

POTENTIAL APPLICATION: Unsignalized intersections with restricted sight distance due to horizontal and/or vertical geometry and patterns of crashes related to that lack of sight distance which have not been ameliorated by less expensive methods[2].

Horizontal Curve on Expressway Approach

EFFECTIVENESS: TRIED

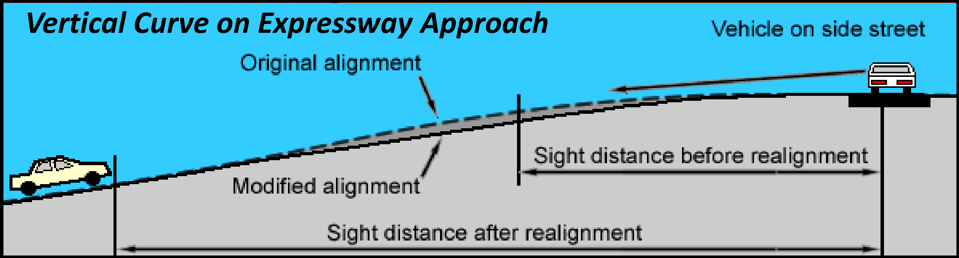
Up to a 20% reduction in crashes related to lack of sight distance, depending on the severity of the sight restriction and the number of intersection quadrants affected[2]. Crash severity is also reduced[24].

COST: EXTREME

TIME: > 2 Years

Independent Vertical Alignments

CAUTION: Other less expensive alternatives should be considered first.



Vertical Curve on Expressway Approach

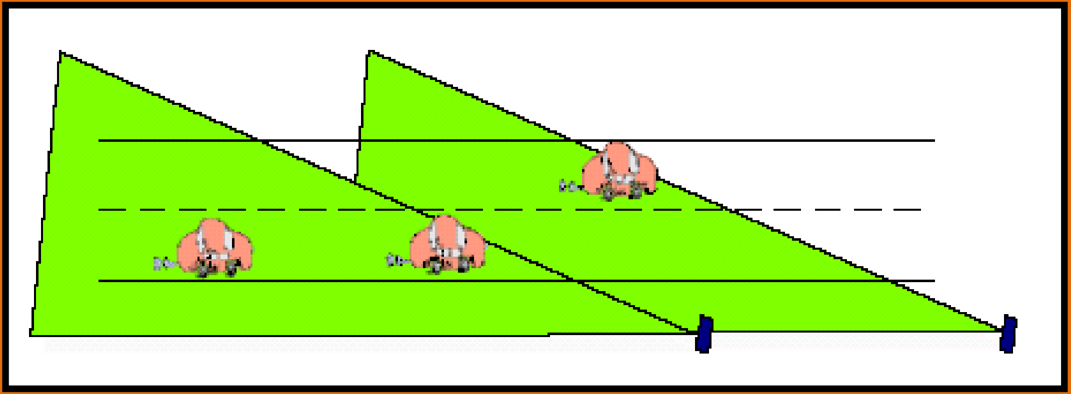
Category E: Assist Minor Road Drivers in Judging/Identifying Gaps

Collisions at rural expressway intersections may occur because drivers stopped on the minor road have difficulty judging gap sizes and oncoming vehicle arrival times while deciding whether or not to enter or cross the expressway. The strategies within this category are intended to aid these minor road drivers in recognizing the presence of approaching expressway traffic and judging the adequacy of available gaps in the expressway traffic stream.

E1: Roadside Markers/Poles

E2: Intersection Decision Support (IDS) Technology (Missouri DOT System)

E3: IDS Technology (Minnesota DOT System)



E1: Roadside Markers/Poles

DESCRIPTION: **Involves placement of static roadside markers (delineators, roadway lighting poles, etc.) and pavement markings at a fixed distance along the expressway in the field of view of minor road drivers to demarcate a hazardous approach zone and assist them in deciding when to accept a gap[2,16,26].**

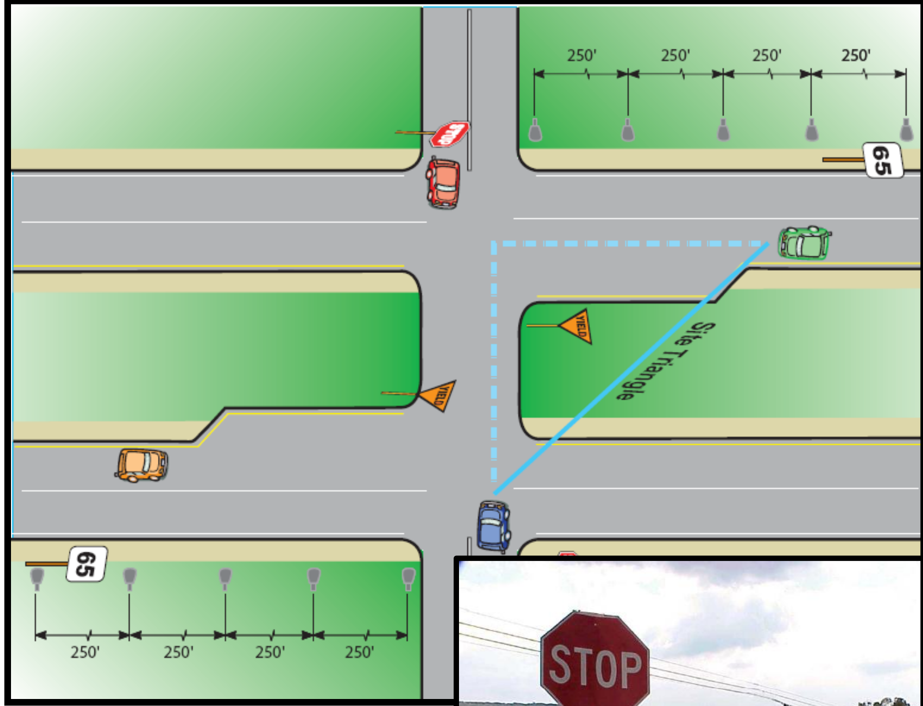
CONCERNS ADDRESSED: **Right-angle and mainline rear-end crashes related to minor road drivers selecting insufficient gaps or lack of expressway driver awareness of the intersection.**

POTENTIAL APPLICATION: **Two-way stop-controlled rural expressway intersections with a pattern of crashes in which minor road/median drivers misjudge arrival times of approaching expressway traffic.**

EFFECTIVENESS: **EXPERIMENTAL** **E**

COST: **LOW** ●○○○

TIME: **<1 Year** ●○○



CAUTION: Drivers on the minor road or in the median must be told (through signing or driver education) not to proceed when an approaching mainline vehicle is within the marked zone. Liability concerns exist with this treatment as the marked zone may not be adequate for speeding vehicles.

E2: Intersection Decision Support (IDS) Technology (Missouri DOT System)

DESCRIPTION: **Involves using "Traffic Approaching When Flashing" intersection warning signs with actuated flashers facing minor road and median drivers to alert them to the detected presence of vehicles approaching on the expressway within a specified distance of the intersection.**

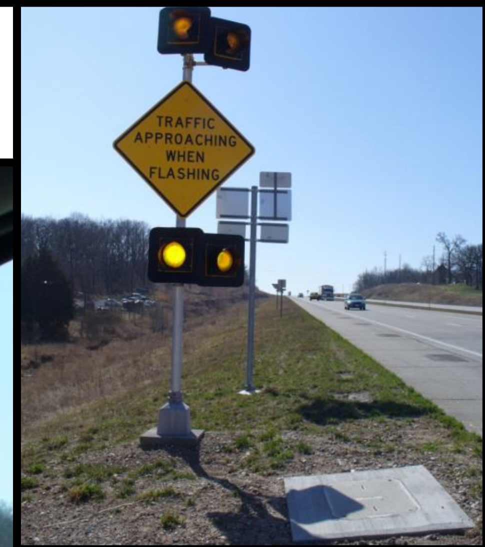
CONCERNS ADDRESSED: **Right-angle and mainline rear-end crashes related to minor road and/or median drivers selecting insufficient gaps in the expressway traffic stream.**

POTENTIAL APPLICATION: **Two-way stop-controlled rural expressway intersections with a pattern of right-angle crashes related to poor gap selection, higher minor road volumes, and/or limited sight distance as a result of horiz./vert. alignment issues or intersection skew.**

EFFECTIVENESS: **EXPERIMENTAL** (E)

COST: **MODERATE** ●●○○

TIME: **<1 Year** ●○○



CAUTION: There is likely an expressway volume threshold at which the beacons would flash continuously, potentially limiting their effectiveness.

E3: Intersection Decision Support (IDS) Technology (Minnesota DOT System)

DESCRIPTION: **Involves installing an automated real-time system utilizing radar to track approaching mainline vehicles, compute their arrival times, and activate the appropriate dynamic message sign to alert minor road and median drivers to their presence and inform them when a safe gap exists for crossing or merging with expressway traffic[16].**

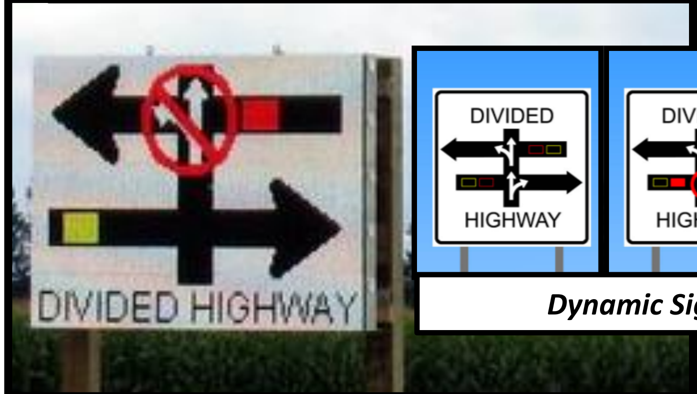
CONCERNS ADDRESSED: **Right-angle and mainline rear-end crashes related to minor road and/or median drivers selecting insufficient gaps in the expressway traffic stream.**

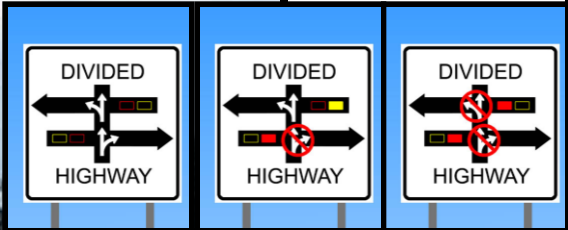
POTENTIAL APPLICATION: **Two-way stop-controlled rural expressway intersections with a pattern of right-angle crashes related to poor gap selection, higher minor road volumes, and/or limited sight distance as a result of horiz./vert. alignment issues or intersection skew[16].**

EFFECTIVENESS: **EXPERIMENTAL** **E**

COST: **HIGH** ●●●○

TIME: **1-2 Years** ●●○





Dynamic Sign Changes

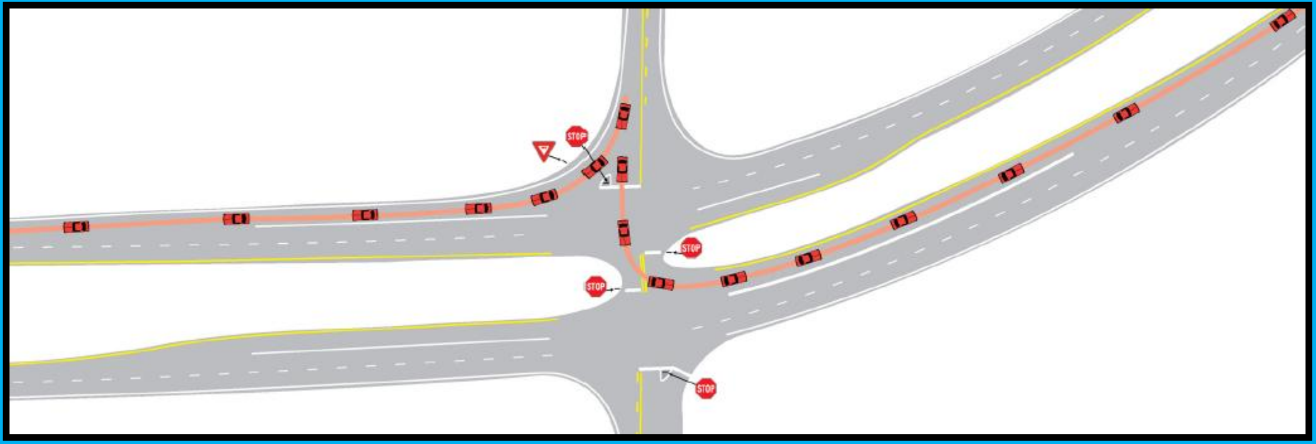
CAUTION: There is likely an expressway volume threshold at which the "Do Not Enter" symbols would be continuously active, potentially limiting the effectiveness of this system.

Category F: Assist Minor Road Drivers in Expressway Merging

Collisions at rural expressway intersections may occur because drivers stopped on the minor road have difficulty judging gap sizes and determining what lane oncoming expressway traffic is in while deciding whether or not to merge into expressway traffic. The strategies within this category are intended to aid these minor road drivers by providing separate acceleration lanes for these merging maneuvers.

F1: Provide Right-Turn Acceleration Lanes

F2: Provide Left-Turn Median Acceleration Lanes (MALs)



F1: Provide Right-Turn Acceleration Lanes

DESCRIPTION: **Involves adding a right-turn auxiliary speed change lane adjacent to the expressway through lanes which allows right-turning minor road vehicles entering the expressway to accelerate to or near expressway speeds before merging into the through lanes. Parallel and tapered designs have been used[2].**

CONCERNS ADDRESSED: **Near-side right-angle and all rear-end collisions related to right-turn entry onto the expressway from the minor road & minor road delay.**

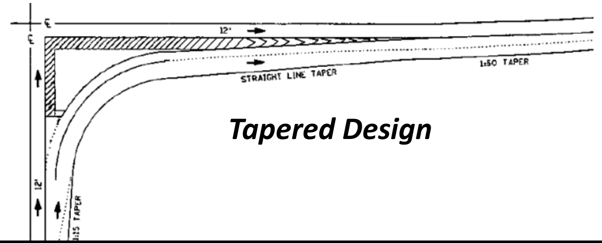
POTENTIAL APPLICATION: **Two-way stop-controlled intersections with relatively high right-turn volumes (particularly trucks) on the minor road, right-turns on an uphill grade, right-turns with sight-distance issues, or those intersections that experience a high proportion of near-side right-angle, rear-end, or sideswipe collisions related to the speed differential caused by vehicles making right-turn movements onto the expressway[2].**

EFFECTIVENESS: **TRIED** **No quantitative estimates available[2].**

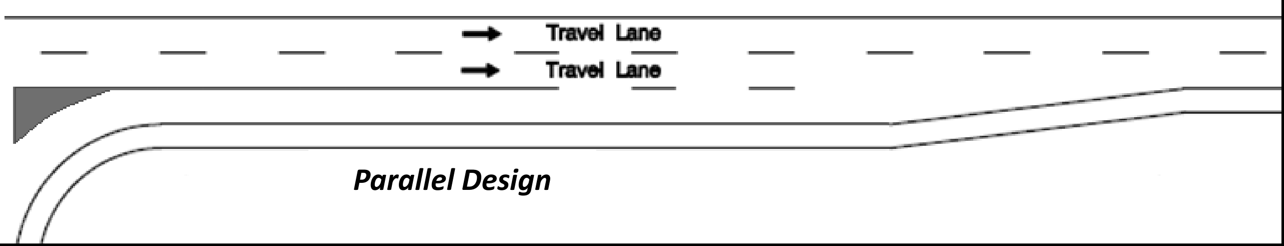
COST: **MODERATE**

TIME: **1-2 Years**

NOTE: Positive guidance into the lane is essential to help avoid minor road rear-end collisions; therefore, significant work may be needed on minor road approaches as well.



Tapered Design



Parallel Design

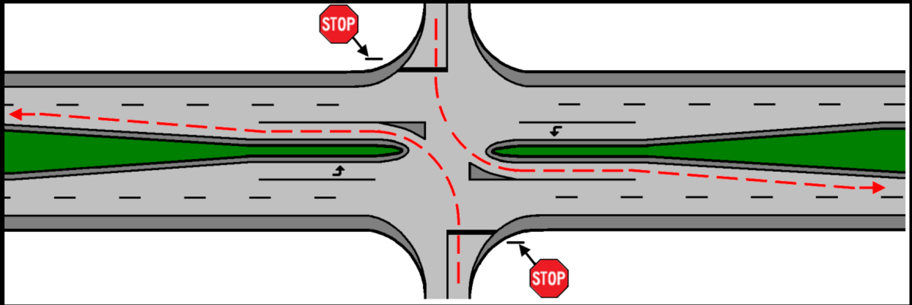
F2: Provide Left-Turn Median Acceleration Lanes (MALs)

DESCRIPTION: Involves adding auxiliary speed-change lanes within the median allowing left-turn minor road traffic to accelerate before merging into the through lanes. Parallel & tapered designs have been used.

CONCERNS ADDRESSED: Far-side right-angle and mainline rear-end collisions related to left-turn entry from the minor road. Also median and/or minor road delay associated with minor road left-turns[27].

POTENTIAL APPLICATION: Two-way stop-controlled intersections with relatively high left-turn volumes from the minor road (75-100 trucks/day[22]), left-turns on an uphill grade, left-turns with sight-distance issues, or where patterns of far-side right-angle, rear-end, or sideswipe collisions occur as a result of left-turn movements onto the expressway and sufficient median width is available[2].

NOTE: Drivers must be able to identify/recognize the MAL from the minor road through signage, markings, or driver education. Design of the median opening should aim to minimize conflicts[2].



EFFECTIVENESS: TRIED (T)

≈ 10-25% reduction in right-angle[16,27],
≈ 40-50% reduction in far-side right-angle[16],
≈ 40-80% reduction in mainline rear-end[16,27].

COST: MODERATE ●●○○

TIME: 1-2 Years ●●○

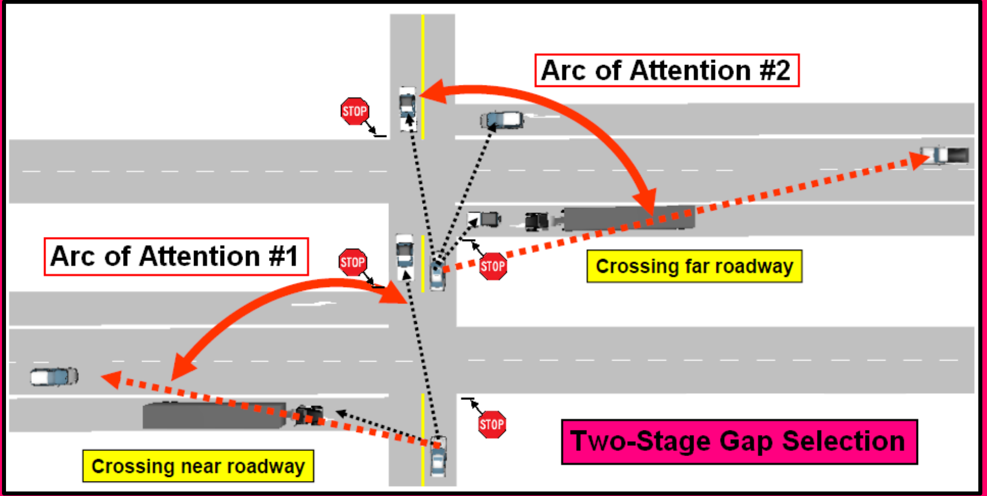
Category G: Positive Guidance Promoting Two-Stage Gap Selection

Collisions at rural expressway intersections may occur because drivers stopped on the minor road try to simultaneously find an acceptable gap in expressway traffic coming from both the left and the right without stopping/yielding in the median to re-evaluate the gap to the right (one-stage gap selection). The strategies within this category are intended to promote two-stage gap selection (pictured) by providing more effective positive guidance to these drivers. Two-stage gap selection is less demanding on the minor road driver because it breaks the crossing or left-turn process into less demanding successive tasks.

G1: Median Delineation with Pavement Marking

G2: Median Signage

G3: Widen/Modify Expressway Median



G1: Median Delineation with Pavement Marking

DESCRIPTION: Includes three potential options to better define the median space with pavement markings, communicate desired vehicle paths and ROW in the median, & create median target value:

1) Dotted left edge line extensions through median,
2) Yield/stop bars in the median, and/or
3) A double yellow centerline in the median.

CONCERNS ADDRESSED: Far-side right-angle & other median collisions related to one-stage gap selection or median vehicle positioning.

POTENTIAL APPLICATION: Two-way stop-controlled expressway intersections experiencing operational and/or safety problems related to vehicle alignment or undesirable driving behavior within the median (i.e., side-by-side queuing, angle stopping, through lane encroachment, one-stage gap selection)[2,16,22].

EFFECTIVENESS: TRIED (T)

No quantitative estimates available[2,16,22].

COST: LOW ●○○○

TIME: <1 Year ●○○

NOTE: Place stop/yield lines as close to expressway through lanes as possible (see Strategy D2). Median pavement markings should be milled in to prevent them from being quickly worn off by median traffic.

G2: Median Signage

DESCRIPTION: Involves supplementing median Yield or Stop signs with warning signs or placards having messages reinforcing median right-of-way by reminding median drivers to look right again for oncoming expressway traffic before proceeding into the far-side expressway lanes; thereby promoting two-stage gap selection.

CONCERNS ADDRESSED: Far-side right-angle collisions related to one-stage gap selection (i.e., drivers not stopping in the median to re-evaluate the gap in traffic coming from the right).

POTENTIAL APPLICATION: Two-way stop-controlled expressway intersections with enough room in the median for vehicle storage and a pattern of far-side right-angle collisions.

OR

OR

OR

EFFECTIVENESS: TRIED T

No quantitative estimates available[16].

COST: LOW

TIME: <1 Year

G3: Widen/Modify Expressway Median

DESCRIPTION: Involves widening the expressway median and/or modifying the median type (depressed-turf, flush-painted, or raised-curb) in the vicinity of intersections, while keeping the median opening length consistent with the crossroad width[22].

CONCERNS ADDRESSED: Far-side right-angle crashes and other collisions related to inadequate median storage, median locking, or lack of expressway driver recognition of the intersection.

POTENTIAL APPLICATION: Rural unsignalized intersections with patterns of right-angle crashes or median locking, those with 800-1000 vpd[28] or serving major truck volumes through the median, or intersections where one-stage gap selection is the only option due to restricted median width and additional right-of-way is available for median expansion. Not advised in high-growth corridors which may require future signalization.

EFFECTIVENESS: TRIED (T)

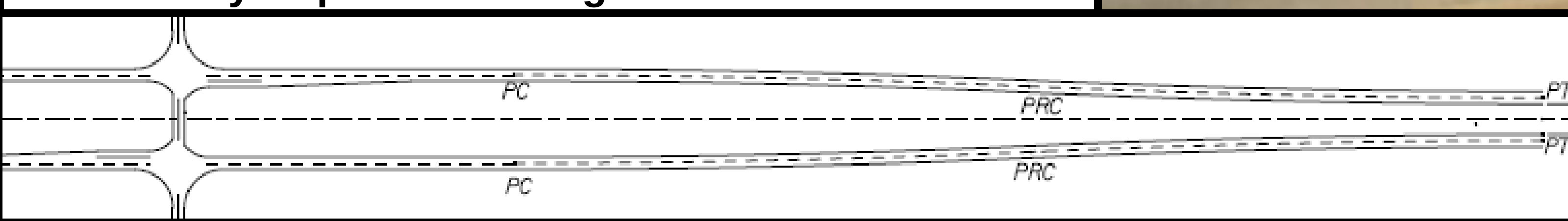
≈ 0.74% to 1.22% reduction in annual crash frequency with every 1 foot increase in median width[22,29].

COST: EXTREME ●●●●

TIME: > 2 Years ●●●

NOTE: May be used with conventional left-turn lanes or offset lefts (D3) and/or side road widening (H6). May also be combined with other strategies such as G1, H2, H7, H8, H9, H10, and/or I1.

Median Lock-up: Left-turn truck unable to straighten out due to limited median width.



Category H: Improve Intersection Recognition (Driver Awareness)

Collisions at rural expressway intersections may occur because one or more approaching drivers are unaware of the intersection until it is too late to avoid a collision. This is a particular problem if the minor road driver does not realize they are approaching a stop-controlled intersection. It is also a problem for drivers approaching unsignalized intersections from high-speed uncontrolled approaches. The strategies within this category are intended to enhance the visibility of intersections and alert drivers to their presence as well as the increased potential for conflicts.

H1: Provide "Divided Highway" & "Cross Traffic Does Not Stop" Placards on Minor Road

H2: Provide Wrong-Way Entry Prevention Signage/Pavement Markings for Minor Road Drivers

H3: Provide Traditional "Stop Ahead" Warning Signs & Pavement Markings on Minor Road

H4: Provide Larger/More Reflective/Overhead/Flashing Signage Along Minor Road

H5: Provide In-Lane Rumble Strips on Minor Road

H6: Provide Divisional/Splitter Island at Mouth of Intersection on Minor Road

H7: Provide Traditional "Intersection Ahead" Warning Signs on Expressway

H8: Provide Enhanced Freeway Style or Diagrammatic Advance Intersection Guide Signs on Expressway

H9: Provide "Watch for Entering Traffic" Dynamic Warning Signs & Flashers with/without Speed Advisory on Expressway

H10: Provide Intersection Lighting

H1: Provide "Divided Highway" & "Cross Traffic Does Not Stop" Placards on Minor Road

DESCRIPTION: **Involves installation of "Divided Highway" and/or "Cross Traffic Does Not Stop" warning placards in combination with Stop signs on minor road approaches. See MUTCD[11] Sections 2B.42 & 2C.59.**

CONCERNS ADDRESSED:
Right-angle and mainline rear-end collisions related to minor road drivers crossing or entering the expressway.

POTENTIAL APPLICATION:
Two-way stop controlled expressway intersections experiencing crashes due to minor road drivers running the stop sign, misinterpreting the expressway as an undivided highway, or misinterpreting the intersection as all-way stop control.

EFFECTIVENESS: **TRIED** (T)
No quantitative estimates available.

COST: **LOW** ●○○○

TIME: **< 1 Year** ●○○

NOTE: According to the MUTCD[11], the Divided Highway Placard is optional when the median width is ≥ 30 ft and the divided highway has an AADT < 400 vpd and a speed limit of ≤ 25 mph. It is not required when the median width is < 30 ft (see the MUTCD's definition of median width).

H2: Provide Wrong-Way Entry Prevention Signage/Pavement Markings for Minor Road Drivers

DESCRIPTION: **Involves installation of signage and pavement markings (such as turn path, median nose delineation, and/or lane use arrow markings) to discourage wrong-way entry onto the expressway (i.e., improper left-turns into the near roadway of the divided highway)[30]. Visibility of the median and the far roadway from the minor road also helps to discourage wrong-way movements. See MUTCD[11] Sections 3B.08 and 3B.20.**

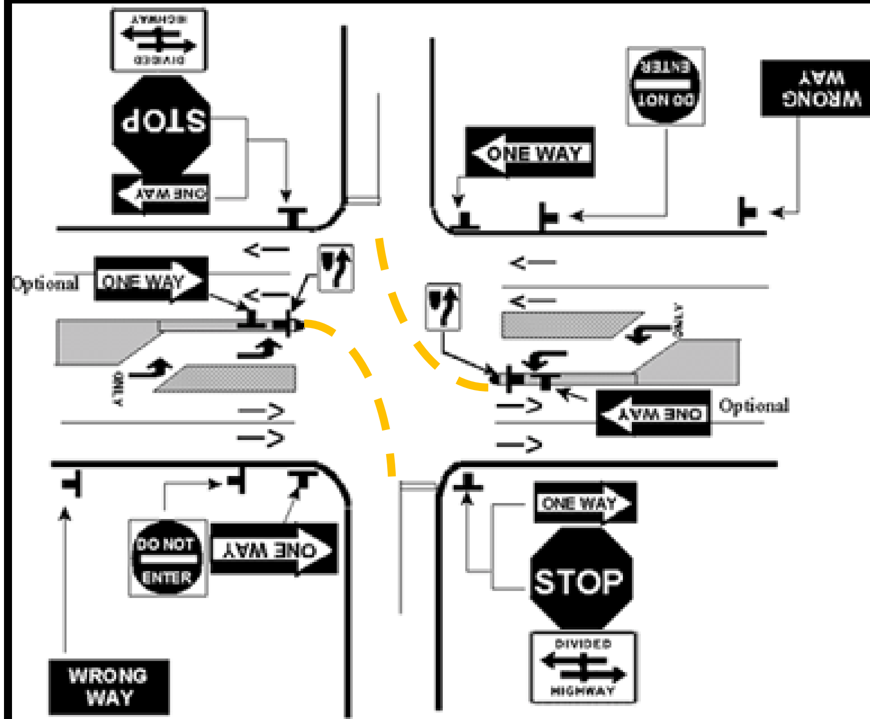
CONCERNS ADDRESSED: **All crashes related to lack of minor road driver awareness of the divided nature of the expressway.**

POTENTIAL APPLICATION: **Unsignalized intersections with a high frequency of crashes related to wrong-way entry, driver confusion/ indecision, or turn vehicle positioning, especially where wide medians ([G3]) and/or offset left-turn lanes ([D3]) are present[30].**

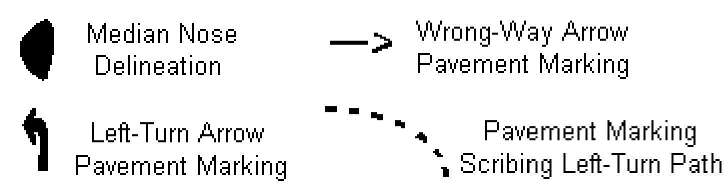
EFFECTIVENESS: **EXPERIMENTAL** **E**

COST: **LOW**

TIME: **< 1 Year**



Potential Additions Include[30]:



NOTE: Pavement markings should be milled in to prevent them from being quickly worn off. Intersection lighting ([Strategy H10]) may also be effective at preventing wrong-way entry and may be combined with this treatment[22].

H3: Provide Traditional "Stop Ahead" Warning Signs & Pavement Markings on Minor Road

DESCRIPTION: Involves installation of signage and supplementary pavement markings to alert the minor road driver to the presence of the stop controlled intersection ahead. See MUTCD[11] Sections 2A.16, 2C.36 and 3B.20.

CONCERNS ADDRESSED: Right-angle or minor road rear-end crashes related to minor road driver lack of awareness of the intersection and/or running of the stop sign.

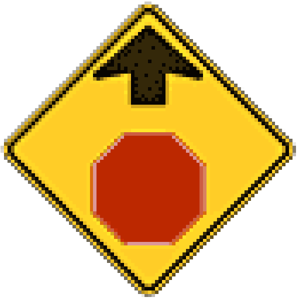
POTENTIAL APPLICATION: Unsignalized intersections not clearly visible to approaching minor road drivers or those with patterns of right-angle or minor road rear-end crashes related to lack of minor road driver recognition of the intersection and/or running the stop sign.

EFFECTIVENESS: TRIED (T)

≈ 13-31% reduction in total crashes & ≈ 8-22% reduction in injury crashes with "Stop Ahead" pavement markings[8,17,31].

COST: LOW

TIME: < 1 Year



OR

H4: Provide Larger/More Reflective/Overhead/Flashing Signage Along Minor Road

DESCRIPTION: **Involves enhancing the conspicuity of standard regulatory, warning, or guide signs (larger, more reflective, overhead, or flashing) along the minor road approaches to alert minor road drivers to the presence of the stop controlled intersection. The flashing red stop sign light may also indicate to minor road drivers that extra caution should be used when selecting a gap. See MUTCD[11] Sections 2A.07, 2A.08, 2A.11, 2A.15, 2A.16, 2A.17, 4L.03, and 4L.05.**

CONCERNS ADDRESSED: **Right-angle or minor road rear-end crashes related to minor road driver lack of awareness of the intersection and/or running the stop sign.**

POTENTIAL APPLICATION: **Unsignalized intersections not clearly visible to approaching minor road drivers, those with patterns of right-angle or minor road rear-end crashes related to lack of minor road driver recognition of the intersection or the stop sign, and where [Strategy H3](#) failed to correct the problem.**

EFFECTIVENESS: **TRIED** **T**

≈ 5% reduction in total crashes, ≈ 8% reduction in rear-end, and ≈ 10-16% reduction in angle crashes with flashing beacons[8,17,32].

COST: **LOW** ●○○○ **TIME:** **< 1 Year** ●○○

H5: Provide In-Lane Rumble Strips on Minor Road

DESCRIPTION: Involves installation of rumble strips on high-speed minor road approaches to alert minor road drivers to the presence of the stop-controlled intersection ahead.

CONCERNS ADDRESSED: Right-angle or minor road rear-end crashes related to minor road driver lack of intersection recognition and/or running the stop sign.

POTENTIAL APPLICATION: Stop-controlled intersections not clearly visible to approaching minor road drivers or those with patterns of right-angle or minor road rear-end collisions related to lack of minor road driver recognition of the intersection or the stop control and running the stop sign. Should be used sparingly and only considered after other strategies (H3 or H4) have failed to correct the safety problem.

EFFECTIVENESS: TRIED

T

While rumble strips are perceived to be effective, their effect on crashes is inconclusive at this time[2,8,17,33,34].

COST: LOW

TIME: < 1 Year

Wheel Path Rumble Strips

Full Width Rumble Strips

H6: Provide Divisional/Splitter Island at Mouth of Intersection on Minor Road

DESCRIPTION: **Involves installation of a "splitter" or raised channelization island on the minor road approach at the mouth of an expressway intersection to separate opposing traffic and narrow the minor road approach. These islands can call an approaching minor road driver's attention to the presence of the intersection, help guide traffic through the intersection, & provide a location to install a second stop sign.**

CONCERNS ADDRESSED: **Right-angle or minor road rear-end crashes related to minor road driver lack of awareness of the intersection and/or stop sign violations.**

POTENTIAL APPLICATION: **Stop-controlled intersections (particularly skewed intersections) not clearly visible to approaching minor road drivers or those with patterns of right-angle or minor road rear-end collisions related to lack of minor road driver recognition of the intersection or the stop control.**

EFFECTIVENESS: **TRIED**

T

≈ 15-68% reduction in total crashes[17,34,35]**, ≈ 30-74% reduction in fatal/injury & angle**[34,35]**, and ≈ 100% reduction in rear-end collisions**[35]**.**

COST: **MODERATE**

TIME: **1-2 Years**

NOTE: May be used in combination with other strategies, particularly **D2** and **D4**, but also **H3**, **H4**, and **H5**.

H7: Provide Traditional "Intersection Ahead" Warning Signs on Expressway

DESCRIPTION: Involves installation of traditional "Intersection Ahead" warning signs on the expressway approaches to alert expressway drivers to the presence of the intersection ahead and the potential for conflicts from turning, crossing, or entering traffic. An advance street name placard is recommended to help identify the intersecting roadway**. See MUTCD[11] Sections 2A.16, 2C.46, and 2C.58.

CONCERNS ADDRESSED: Right-angle or mainline rear-end crashes related to lack of expressway driver awareness of the intersection and unexpected stops, turns, and weaving.

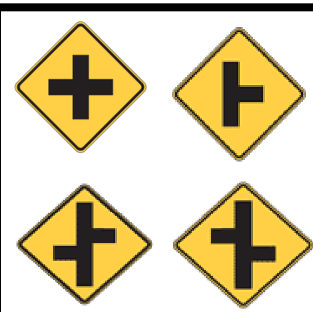
POTENTIAL APPLICATION: Two-way stop controlled intersections not clearly visible to approaching expressway drivers or those with patterns of right-angle, or mainline rear-end crashes related to lack of expressway driver recognition of the intersection.

EFFECTIVENESS: TRIED T

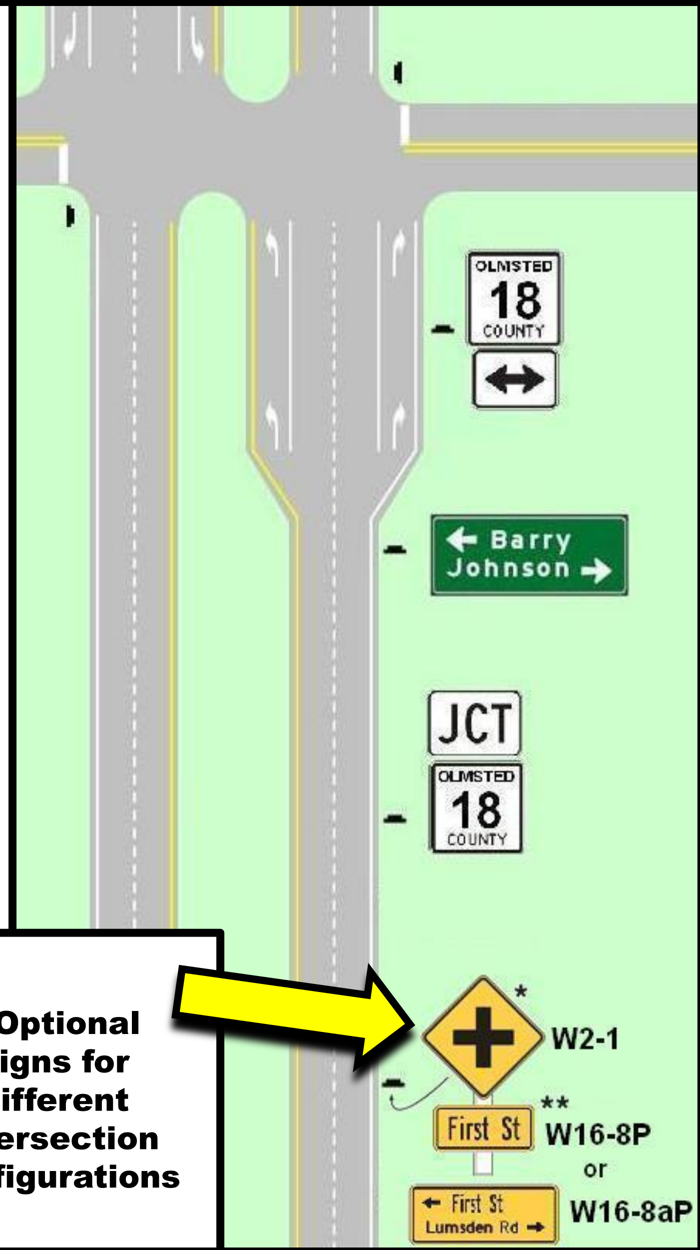
No quantitative estimates available[8].

COST: LOW

TIME: < 1 Year



* Optional Signs for Different Intersection Configurations

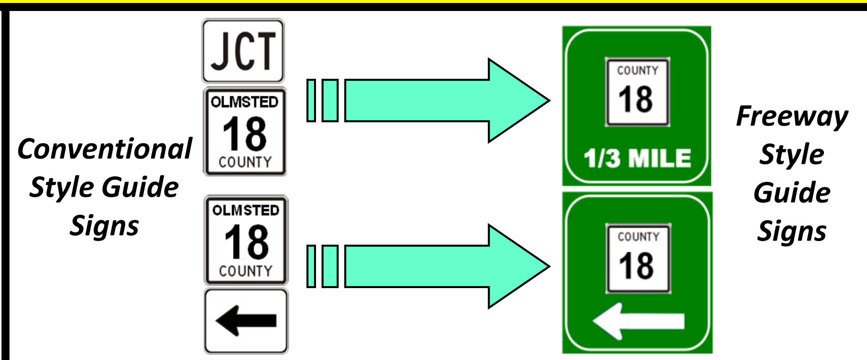


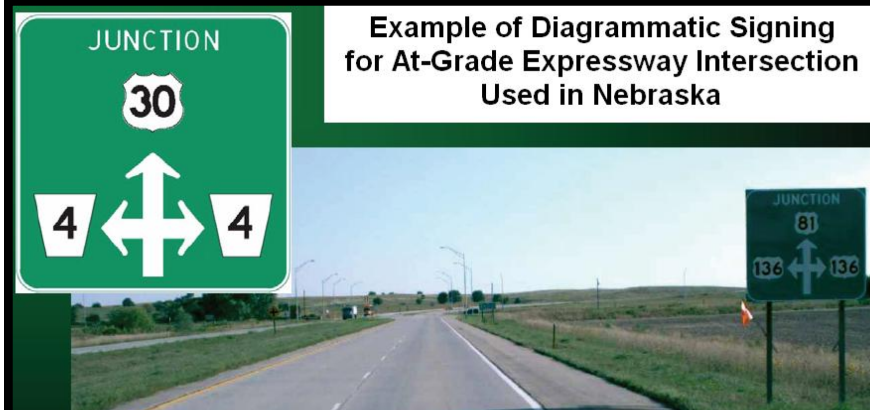
H8: Provide Enhanced Freeway-Style or Diagrammatic Advance Intersection Guide Signs on Expressway

DESCRIPTION: **MUTCD[11] Section 2E.29 states that intersection guide sign types for conventional roads be used at expressway intersections, but gives the option of providing enhanced freeway-style or diagrammatic advance intersection guide signs to alert expressway drivers to the presence of the intersection and the potential for conflicts from turning, crossing, or entering traffic.**

CONCERNS ADDRESSED: **Right-angle or mainline rear-end crashes related to lack of intersection recognition by expressway drivers and unexpected stops, turns, or weaving.**

POTENTIAL APPLICATION: **Two-way stop controlled intersections not clearly visible to approaching expressway drivers, higher/peak minor road volumes, patterns of right-angle or mainline rear-end crashes related to lack of expressway driver recognition of the intersection and [Strategy H7] failed to correct the problem. This treatment should be used rather sparingly to command attention.**





Example of Diagrammatic Signing for At-Grade Expressway Intersection Used in Nebraska

NOTE: Street names and/or destinations may be added to the freeway-style or diagrammatic signs.

EFFECTIVENESS: **TRIED**

T

≈ 6% increase in total crashes with ≈ 30% decrease in right-angle crashes[16].

COST: **LOW**

TIME: **< 1 Year**

H9: Provide "Watch For Entering Traffic" Dynamic Warning Signs & Flashers with/without Speed Advisory on Expressway

DESCRIPTION: Involves installation of advance intersection warning signs with actuated flashers and/or advisory speed placards to alert expressway drivers to proceed with caution due to the detected presence of vehicles on the minor road or in the median at the intersection ahead.

CONCERNS ADDRESSED: Right-angle or mainline rear-end collisions related to a combination of lack of expressway driver awareness of the intersection and minor road drivers selecting insufficient gaps.

POTENTIAL APPLICATION: Two-way stop-controlled intersections not clearly visible to approaching expressway drivers, higher/peak minor road volumes, or patterns of right-angle or mainline rear-end collisions related to lack of expressway driver recognition of the intersection and Strategies H7 or H8 failed to correct the problem. There is likely a minor road volume threshold where the beacons could be set to flash continuously and minor road/median detection would not be necessary.

EFFECTIVENESS: TRIED

T

≈ 40-60% overall crash reduction with ≈ 30-60% reduction in right-angle crashes & reduced crash severity[16].

COST: LOW

TIME: < 1 Year

H10: Provide Intersection Lighting

DESCRIPTION: **Involves improving visibility of an intersection and enhancing intersection sight distance at night by providing destination or full intersection lighting .**

CONCERNS ADDRESSED: **All intersection-related collisions (especially right-angle, rear-end, and wrong-way entry) related to lack of driver recognition of the intersection, especially during night-time hours.**

POTENTIAL APPLICATION: **Unsignalized, unlit intersections with substantial patterns of night-time crashes related to lack of driver recognition of the intersection or the divided nature of the expressway.**

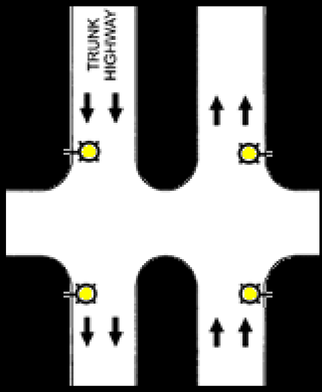
EFFECTIVENESS: **PROVEN**

≈ 8-60% reduction in night-time crash rates & reduced severity[2,8,16].

COST: **HIGH**

TIME: **1-2 Years**

NOTE: Destination lighting is only intended to guide a driver to an intersection and may not provide sufficient illumination to increase visibility. Full intersection lighting is specifically designed to increase visibility. May be combined with **Strategy H2**.



Category I: Reduce Expressway Operating Speeds

On some high-speed expressway intersection approaches, implementing measures to reduce operating speeds may provide an approaching expressway driver with additional time to react to unanticipated conflicts and make safer intersection-related decisions. Reduced operating speeds would also increase the time-to-arrival of an approaching expressway vehicle, thereby increasing the time gap for minor road traffic to cross/merge. It may also reduce crash severity. The strategies within this category are intended to reduce operating speeds on high-speed rural expressway intersection approaches.

I1: Expressway Speed Zoning Through Intersections

I2: Targeted Intersection Speed Enforcement

I1: Expressway Speed Zoning Through Intersections

DESCRIPTION: **Involves reducing the expressway speed limit in the vicinity of an intersection or posting an advisory speed limit through an intersection. See MUTCD[11] Section 2C.38.**

CONCERNS ADDRESSED: **Right-angle, mainline rear-end, and left-turn leaving collisions related to high expressway operating speeds, large speed differentials, or lack of expressway driver awareness of the intersection.**

POTENTIAL APPLICATION: **Two-way stop controlled expressway intersections experiencing a high frequency of crashes potentially related to high speeds (particularly right-angle, mainline rear-end, and left-turn leaving collisions), where intersection recognition seems to be an issue for expressway drivers or where sight distance issues exist.**

EFFECTIVENESS: **TRIED**

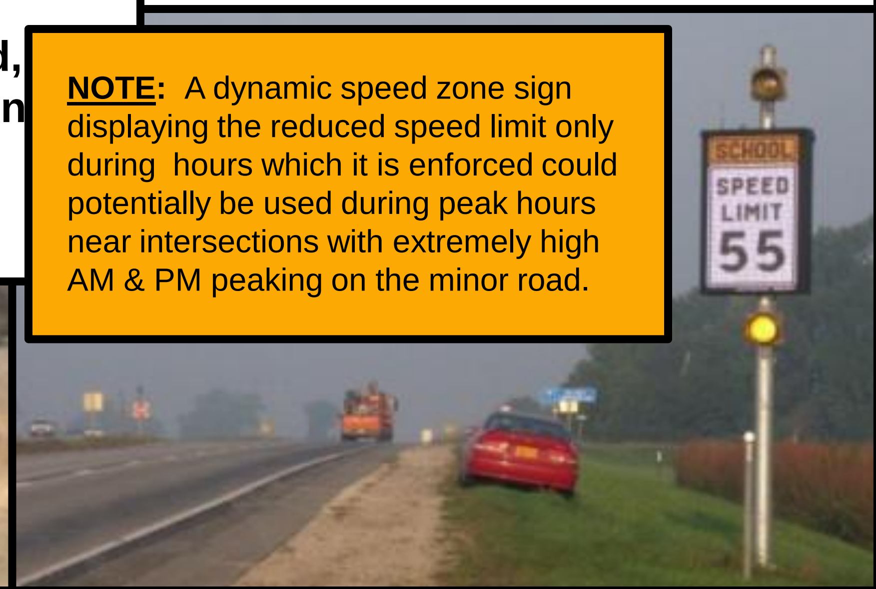
T

No quantitative estimates available[2].

COST: **LOW**

TIME: **<1 Year**

NOTE: A dynamic speed zone sign displaying the reduced speed limit only during hours which it is enforced could potentially be used during peak hours near intersections with extremely high AM & PM peaking on the minor road.



I2: Targeted Intersection Speed Enforcement

DESCRIPTION: Involves law enforcement agencies targeting key intersections of concern with speed enforcement & monitoring.

CONCERNS ADDRESSED: High-speeds and related severe crashes (right-angle and mainline rear-end).

POTENTIAL APPLICATION: Unsignalized intersections where speed violations/citations and patterns of severe crashes (right-angle, rear-end, and left-turn leaving) related to speed violations indicate unusually hazardous conditions due to illegal driving practices[2].

EFFECTIVENESS: PROVEN

Reduces mean speed and number of speed-related collisions for a short duration (days/weeks)[2]. This strategy tends to lose its effectiveness quickly when the enforcement is not present.

COST: LOW

TIME: <1 Year

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