



Toolbox of Countermeasures and Their Potential Effectiveness to Make Intersections Safer

Introduction

Studies included in the NCHRP 17-18 (3), [Guidance for Implementation of the AASHTO Strategic Highway Safety Plan](#), as well as in other research by governmental entities have produced estimates of crash reductions that might be expected if a specified improvement or group of improvements are implemented. Three tables have been developed that attempt to summarize some of the available information. Readers will note that, by and large, there may be little consensus regarding the value of crash reduction factors for a number of countermeasures. The transportation engineering discipline needs to develop a base of statistically sound before-and-after studies for extended periods of time to overcome the deficit in countermeasure effectiveness data.

Use of the Tabular Data

The data in this briefing sheet represent a number of countermeasure effectiveness studies and includes ranges of effectiveness realized from one or more sources. Readers are encouraged to obtain and review original source documents for more detailed information. It must be emphasized that the potential effectiveness values, for example percentage reduction in crashes, represent order-of-magnitude estimates only. Traffic engineers need to consider site-specific environmental, geometric and operational conditions before making a judgment regarding those countermeasures that will be applied to an intersection.

Traffic engineers and other transportation professionals can use the information contained in this briefing sheet when the public or an elected or appointed official asks a question such as:

What is the range of solutions that might be considered at the signalized intersection of Maple and Elm streets due to the high number of total crashes and left-turn crashes? What low-cost improvements can be tried first? If these improvements do not give us a higher degree of safety, what else can we try?

The countermeasure effectiveness tables in this briefing package include:

- ◆ **Table 1: Signalization Countermeasures at Signalized Intersections.** Specific categories of countermeasures included in this table are signal timing and phasing improvements, signal hardware and combination signal and other improvements.
- ◆ **Table 2: Geometric Countermeasures at Unsignalized Intersections.** Specific categories of countermeasures included in this table are left-turn treatments, right-turn treatments and other geometric improvements.
- ◆ **Table 3: Signs/Markings/Operational Countermeasures (Applicability Notes for Signalized and/or Unsignalized Intersections).** Specific categories of countermeasures included in this table are: signs, pavement markings and modifications, and regulatory, lighting and operational improvements.



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Table 1:
Signalization Countermeasures at Signalized Intersections

Numbers in [n] indicate references used

Numbers prior to the [n] represent the range of % crash reduction that might be expected from implementing a given improvement.

- Countermeasure/Crash Type identified; however no estimate of effectiveness is provided.

Improvement Type(s)	Cost	Potential Effectiveness (Percentage Reduction)							
		Total Crashes	Right Angle Crashes	Left Turn Crashes	Rear-end Crashes	Sideswipe	Pedestrian	Red-Light Running	Older Driver
SIGNAL OPERATIONS IMPROVEMENTS									
Interconnect/Coordinate Traffic Signals; Optimization	Medium	15-17 [1]	25-38 [12]		●			● [2]	
Increase/Modify Clearance Intervals	Low	4-31 [1,9,10]	1-30 [1,9]		●			● [2]	
Improve Signal Timing (General)	Low	10-15 [1]	●	●		●		●	
Add Protected/Permissive LT Phase	Medium	4-10 [1,9]		40-64 [1,9]					
Use Green Arrow/ Protected Left Turns/Movement Signal Phasing	Low	3 [9]		98 [9]					●
Use Split Phases	Low	25 [11]		●	●	●			
Use Leading Pedestrian Interval	Low						5 [8]		
Add Pedestrian Phase	Medium	23-25 [1]					7-60 [1,8]		
Add Left-Turn Phasing to an Existing Signal	Medium	23-48 [6, 12]		63-70 [1]			5 [8]		
Provide Green Extension (Advance Detection)	Variable				●			●	
Install Signal Actuation	Variable				●	●			
Assume Slower Walking Speeds for Pedestrian Signal Timing	Low						●		●
Provide Advance Warning of Signal Changes at Rural Signalized Intersections	Medium	●	●		●			●	
Remove Signals from Late Night/Early Morning Flash	Low	29 [9]	80 [9]						
Consider Restricting Right-Turns-on-Red	Low						●		
Consider Installation of Pedestrian Countdown Signals (incremental cost)	Low						●		
Consider Installation of Animated Eye Signals (Incremental cost)	Low						●		
SIGNAL HARDWARE									
Install Larger (12-Inch) Signal Lenses	Low	10-12 [1,9]	48 [9]		●	●		●	●
Install Flashing Beacon at Intersection	Medium	30-38 [1]						● [2]	
Install Flashing Beacon at Advance of Intersection	Medium	25-28 [1]						● [2]	
Replace Pedestal Mounted Signal with Mast Arm	High	28-43 [12]	●						
Install Backplates on Existing Signals	Low	2-24 [1,9]	7-93 [1,5,9]		●	●		● [2]	●
Optically Programmed Signal Lenses	Low	15-18 [1]						●	
Provide Louvers, Visors, Special Lenses so Drivers are able to View Signals only for their Approach	Low				●	●		●	
Upgrade Signal Controller	Medium	20-22 [1 8, 11]		●	●	●			
Relocate/Shield Signal Hardware in Clear Zone. Signal Hardware Should Not Obstruct Sight Lines.	Medium	[6]	●		●	●			
Install Additional Signal Heads	Medium	10 [9]	42 [9]		●	●		●	●
Install More Overhead Traffic Signals	High	●	●		●			●	●
Provide Two Red-Signal Displays within each Signal Head to Increase Conspicuity of the Red Display	Medium							● [2]	
Use LED Traffic Signal Module.	Medium							● [2]	
Stripe for Left-Turn Lane within Existing Roadway	Low	26 [9]		66 [9]					
Red T-Display	Medium	9 [9]	36 [9]						

Table 1 (continued)
Signalization Countermeasures at Signalized Intersections

Improvement Type(s)	Cost	Potential Effectiveness (Percentage Reduction)							
		Total Crashes	Right Angle Crashes	Left Turn Crashes	Rear-end Crashes	Sideswipe	Pedestrian	Red-Light Running	Older Driver
COMBINATION SIGNAL AND OTHER IMPROVEMENTS									
Construct Left-Turn Lanes with Signal Upgrades	High	●		●	●				
Left-Turn Lane, Signal and NO Turn Phase	High	21-25 [1]		46-54 [1]	●				
Left-Turn Lane, Signal PLUS Turn Phase	High	25-36 [1]		43-45 [1]	●				
Add Left-Turn Phasing AND Turn Lanes to an Existing Signal	High	46-69 [12]	●	●	●				
Removal Signal, Develop a Program to Identify and Remove Unwarranted Signals.	Low	50-53 [1]			●	●			
Install 12" Signal Heads and SIGNAL	Low	11 [9]	36 [9]						

Table 2:
Geometric Countermeasures at Unsignalized Intersections

Improvement Type/Special User	Cost	Potential Effectiveness (Percentage Reduction)					
		Total Crashes	Right Angle	Left Turn	Rear-end	Sideswipe	Older Driver
LEFT TURN TREATMENTS							
Add Left-Turn Lane, No Signal	Medium-High	25-41 [1,9]		50-86 [1,9]			
Provide Separate Left-Turn Lane, One Major Road Approach, and 3-Leg Intersection.	Medium	44/rural 33/urban [5]			●		
Provide Separate Left-Turn Lane, One Major Road Approach, and 4-Leg Intersection.	Medium	28/rural 27/urban [5]			●		
Provide Separate Left-Turn Lane, 2 Major Road Approaches	High	42 [5]					
Provide Adequate Length Turn Lane	Medium	15-30 [1,7,10]			●		
Provide Indirect Left Turns	Variable		●	●	●		
Provide Offset Left Lanes	Variable	●		●	●	●	● [1]
Provide Left-Turn Acceleration Lane at Divided Highway Intersections	Medium-High				●		
Add Continuous Left-Turn Lanes	High	● [1]					
RIGHT-TURN TREATMENTS							
Provide Right-Turn Lane, One Major Approach, on Rural 4-Lane, Intersection	Medium	14 [5, 10]			●		
Exclusive Right-Turn Lanes, Two Major Approaches, on Rural 4-Lane, Intersection	Variable	14-27 [5]			●		
Provide Right-Turn Acceleration Lanes	Variable	●			●	●	
Provide Longer Right-Turn Lane	Variable	●					
Provide Offset Right-Turn Lane	Variable	●		●			● [1]
Add Right-Turn Lane	Medium	24-30 [1]					

Table 2 (continued on page 4)

Table 2 (continued)
Geometric Countermeasures at Unsignalized Intersections

Improvement Type/Special User	Cost	Total Crashes	Potential Effectiveness (Percentage Reduction)				
			Right Angle	Left Turn	Rear-end	Sideswipe	Older Driver
OTHER/GEOMETRIC IMPROVEMENTS							
Shoulder Bypass Lanes; Rural Intersections.	Low				●		
Move Intersection Away from Curve.	High	25 [1,7,8]	●		●	●	
Horizontal/Vertical Realignment of Approaches.	High	● [7]					
Raised Medians Near Major Intersections.	Medium-High	25 [6,1,7,8]					
Continuous Two-Way Left-Turn Lanes to Separate Left Turn and Through Traffic	High	30-40 [1,7,8]			●		
Convert 4-Leg to Two, 2-T Intersections	High	57 [5,10]					
Convert Two-T Intersections to One 4-Leg.	High	● [7]					
Close or Relocate High Risk Intersections	Variable	100 [7]					
Full Width Paved Shoulders. No Shoulder Width Less than 8 ft.	Variable	2.8% per ft. of additional shoulder width [7]			●		
Install Splitter Islands on the Minor Road Approach where the Intersection or STOP Sign is not Visible to Motorists.	Medium	NCOE [7]					
Remove Intersection Skew Angle (of less than 80 degrees); Realign Intersection	High	40-50, [1,10]					
Increase Curb Turning/Edge of Pavement Radii	Medium	15-21 [1,7]			●		● [1]
Widen Approaches to Handle Turns	Medium	[7]			●	●	
Roundabouts at Appropriate Locations	High	38, Total Crashes 76, Injuries 90, Fatalities [7]					
Clear Sight Triangle on Stop or Yield Controlled Approaches	Low	● [7]	●				
Clear Sight Triangle in the Medians of Divided Highways Near Intersections	Low	● [7]					
● Countermeasure/Crash Type identified; however no estimate of effectiveness is provided.							

Table 3:
Signs/Markings/Operational Countermeasures Applicability
Noted for Signalized and/or Unsignalized Intersections

Improvement Type	Applicability	Cost	Potential Effectiveness (Percentage Reduction)						
			Total Crashes	Right Angle	Rear End	Side-swipe	Pedestrian	Red-Light Running	Older Adults
SIGNS									
Install SIGNAL AHEAD Sign	Signalized Intersection	Low	3-40 [7,9, 11]	35 [9]	●	●		● [2]	
Install LEFT TURN Signal Sign	Signalized Intersection	Low						● [2]	
Install SLIPPERY WHEN WET Sign	Signalized Intersection	Low						● [2]	
Enhanced Signing and Delineation	Unsignalized Intersection	Low	● [7]	●	●				
Supplementary STOP Signs Mounted Over the Roadway	Unsignalized Intersection	Low	● [7]	●					
Install YIELD TO PEDESTRIAN Sign	Undefined	Low					10 [8]		
PAVEMENT MARKINGS/MODIFICATIONS									
Install Raised Pavement Markings	Undefined		6-13 [1] 20-30 (Night) 20-46 (Wet, Night)						●
Use Wider Pavement Markings	Undefined								●
Install Rumble Strips on Intersection Approaches	Undefined		2-44 [1]; NCOE [7]	●					

Table 3 (continued)
Signs/Markings/Operational Countermeasures Applicability Noted for Signalized and/or Unsignalized Intersections

Improvement Type	Applicability	Cost	Potential Effectiveness (Percentage Reduction)						
			Total Crashes	Right Angle	Rear End	Side-swipe	Pedestrian	Red-Light Running	Older Adults
PAVEMENT MARKINGS/MODIFICATIONS (continued)									
Resurfacing	Undefined		7-59 [1]; W, 40-54 [1]						
Add Stop Bars/Crosswalks	Signalized Intersection		10-25 [10]	●	●	●			
Install Raised Crosswalk	Undefined						8 [8]		
Groove Pavement for Skid Resistance	Undefined		1-65 [1]; 25 [11] Wet- 42-75 [1]			●			
Angled Median Crosswalk	Undefined	Medium	12 [8]						
Add Stop bars, Wider Stop Bar on the Minor Road Approach; and Short Segments of Centerlines	Undefined		10-27 [1,9, 11,13]	● [5] 47 [9]					
Move Vehicle Stop Line Farther Back from Crosswalk AND Add Sign STOP HERE FOR PEDESTRIANS	Signalized Intersection	Low					●		
STOP AHEAD and STOP Messages on Pavement	Undefined	Low	6 [9]	● [5] 30 [9]					
Add Centerlines, Stop Bars and Replace 24 in. STOP Signs	Unsignalized	Low	45 [9]	67 [9]					
Double Indicated STOP Signs	Unsignalized	Low	11 [9]	36 [9]					
Add Centerlines and Move Stop Bars to Extended Curb Lines.	Unsignalized	Low	29 [9]	24 [9]					
Add Centerlines, Move STOP Bars to Extend Curb Lines, and Add Double-Indicated STOP Signs	Unsignalized	Low	9 [9]	0 [9]					
Provide Dashed Pavement Lining to Guide Left-Turning Vehicles Through Selected Intersections	Undefined	Low	● [1]						
Signed and Marked Crosswalks. For Greatest Effectiveness, Include Curb Ramps, Curb Extensions	Unsignalized Intersection	Low	25-48 [1]				●		
Use Rumble Strips Prior to Rural STOP Signs	Rural, Unsignalized Intersection	Low	35 [8]						
Rumble Strips and SIGNAL AHEAD Warning Sign and Pavement Marking with Message SIGNAL AHEAD	Signalized Intersection	Medium						● [2]	
Replace YIELD Signs with STOP Signs	Unsignalized	Low	29 [9]	9 [9]					
REGULATORY									
2-Way to Multi-Way Stop	Unsignalized Intersection	Low	53-74 [4,9,11]	84 [9]	●	●			
Restrict/Eliminate RTOR	Signalized Intersection	Low	20-25 [1]	●	●		●		
Eliminate Parking that Restricts Sight Distance	Undefined	Low	8-90 [1, 7, 11]						
Restrict Driveways Near Intersections; Right Turn In and Out Movements Only	Unsignalized Intersection Signalized Intersection	Low	● [1,7]						
Allow Left Turns In, but Prohibit Left Turns Out at Selected Access Points (Access Management)	Unsignalized Intersection Signalized Intersection	Low	● [1,7]						

Table 3 (continued on page 6)

Table 3 (continued)
Signs/Markings/Operational Countermeasures Applicability Noted for Signalized and/or Unsignalized Intersections

Improvement Type	Applicability	Cost	Potential Effectiveness (Percentage Reduction)						
			Total Crashes	Right Angle	Rear End	Side-swipe	Pedestrian	Red-Light Running	Older Adults
LIGHTING									
Improve Visibility of the Intersection by Providing Lighting	Unsignalized Intersection Signalized Intersection	Medium	19-75 [1, 7, 8] Night- 18-70 [1]	●	●				●
Improve Visibility of the Existing Rural Intersections and Urban Corridors by Providing Lighting	Undefined	Medium	25-50 [1] N-42-50 [1]						●
OPERATIONAL									
Add Signal to a Unsignalized Intersection when Warranted	Unsignalized	High	20-45 [1,9]	68 [9]					
Add Raised Medians Near Intersections	Undefined		25 [1,10,12]				●		
Install Flashing Beacons	Unsignalized Intersection		● [1]	●					
Improve Access Control Near Intersections	Unsignalized Intersection Signalized Intersection		● [1]						
Refuge Islands	Undefined						56 [8]		
Pedestrian Overpasses/Underpasses	Unsignalized Intersection Midblock	High					13 [8] 90-95 [1]		
Mid-block Traffic Signal	Midblock	High					52 [8]		
Far-side Bus Stops	Unsignalized Intersection Signalized Intersection						1 [8]		
Install Raised Medians	Unsignalized Intersection Signalized Intersection	Medium					69 [8]		
Speed Reduction and Enforcement	Unsignalized Intersection Signalized Intersection	High					70 [8]		
Cut Back Vegetation, Embankments as Far as Possible at Existing Stop-Signed Controlled Intersections	Unsignalized Intersection Signalized Intersection		[5]						
● Countermeasure/Crash Type identified; however no estimate of effectiveness is provided.									

References

- Agent, Kenneth R. et. Al. *Development of Accident Reduction Factors. Research Report KTC-96-13.* Kentucky Transportation Center College of Engineering, June 1996.
- Institute of Transportation Engineers. *Engineering Countermeasures to Reduce Red-Light Running.* Washington, DC: ITE, 2003. <http://safety.fhwa.dot.gov/rtr/rtrreport/RLRbook.pdf>
- FHWA *Older Driver Handbook.*
- Harwood, D.W., F. M. Council, E. Hauer, W. E. Hughes, and A. Vogt. *Prediction of the Expected Safety Performance of Rural Two-Lane Highways,* Report No. FHWA-RD-99-207. Washington, DC: Federal Highway Administration, 2000.
- Institute of Transportation Engineers. *Traffic Safety Toolbox: A Primer on Traffic Safety.* Washington, DC: ITE, 1999.
- NCHRP 17-18 (3). Initial Draft Compendium of Strategies, Signalized Intersections, Phase II. Draft April 29, 2002.
- NCHRP, 500. *Volume 5: A Guide for Addressing Unsignalized Intersection Collisions.* http://gulliver.trb.org/publications/nchrp/nchrp_rpt_500v5.pdf
- MetroPlan Orlando. *Orlando Urban Area Arterial Pedestrian Crash Study.* Orlando: MetroPlan Orlando, July 12, 2000.
- Polanis, Stanley F. *Low Cost Safety Improvements.* City of Winston-Salem, North Carolina, November 2003.
- Retting, R. M. Greene. *Influence of Traffic Signal Timing on Red-Light Running and Potential Vehicle Conflicts at Urban Intersections,* Transportation Research Record 1595. Washington, DC: TRB, 1997.
- SEMCOG. *Traffic Safety Manual,* Second Edition. September 1997. http://www.semco.org/TranPlan/TrafficSafety/assets/Safety_Manual.pdf
- Thomas, Gary B. and Daniel J. Smith. *Effectiveness of Roadway Safety Improvements, Final Report.* Highway Division of the Iowa Department of Transportation, CTRE Management Project 00-61, March 2001.
- TEXDOT 1995.

Other References Consulted

- Pedestrian-Bicycle Information Center Web site. <http://www.walkinginfo.org>
- South Dakota Department of Transportation. *Development of South Dakota Accident Reduction Factors: SD 98-13,* August 1998. http://www.state.sd.us/Applications/HR19ResearchProjects/Projects/SD1998_13_final_report.pdf