Countermeasures for Traffic Signals and Pedestrians

Course No: C01-024

Credit: 1 PDH

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Course Document

The study document accompanying this course consists of the following two issue briefs published by the U.S. Department of Transportation Federal Highway Administration:

"Traffic Signals" FHWA-SA-10-005, November, 2009

and

"Toolbox of Countermeasures and Their Potential Effectiveness for Pedestrian Crashes" FHWA-SA-014, May, 2008.

5 ISSUE BRIEFS

Traffic Signals

The introduction to this issue brief provides an overview of traffic signals (purpose, warrants for signal installation, advantages, disadvantages, and factors to consider) followed by an introduction to the contents of this issue brief (crash reduction factors, presentation of the crash reduction factors, and using the tables).

Purpose of Traffic Signals

Traffic signals are used to assign vehicular and pedestrian right-of-way. They are used to promote the orderly movement of vehicular and pedestrian traffic and to prevent excessive delay to traffic.

Traffic signals should not be installed unless one of the warrants specified by the *Manual on Uniform Traffic Control Devices* (MUTCD) has been satisfied. The satisfaction of a warrant is not in itself justification for a signal. A traffic engineering study must be conducted to determine whether the traffic signal should be installed. The installation of a traffic signal requires sound engineering judgment, and must balance the following, sometimes conflicting, goals:

- Moving traffic in an orderly fashion.
- Minimizing delay to vehicles and pedestrians.
- Reducing crash-producing conflicts.
- Maximizing capacity for each intersection approach.

Where Should a Signal Be Installed?

The MUTCD lists eight warrants for the placement of traffic signals. Readers are encouraged to review Part 4 of the MUTCD for more specific information regarding signal warrants. Access management considerations and the spacing of signals on arterial roadways are critical elements of system efficiency and operational safety. The basic question that must be answered is, “Will this intersection operate better with or without a traffic signal?”

Advantages of Signals

Traffic signals that are properly located and operated are likely to:

- Provide for orderly movement of traffic.
- Increase traffic capacity of the intersection.
- Reduce the frequency of certain types of crashes (e.g. right-angle crashes).
- Provide for continuous or nearly continuous movement of traffic along a given route.
- Interrupt heavy traffic to permit other traffic, vehicular or pedestrian, to cross.

Disadvantages of Signals

Traffic control signals are often considered a panacea for all traffic problems at intersections. This belief has led to the installation of traffic control signals at many locations where they are not needed and where they may adversely affect the safety and efficiency of vehicular, bicycle, and pedestrian traffic.

Even when justified by traffic and roadway conditions, traffic control signals can be ill designed, ineffectively placed, improperly operated, or poorly maintained. Unjustified or improper traffic control signals can result in one or more of the following disadvantages:

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- Excessive delay.
- Excessive disobedience of the signal indications.
- Increased use of less adequate routes as road users attempt to avoid the traffic control signals.
- Significant increases in the frequency of crashes (especially rear-end crashes).

As angle crashes tend to be more severe than rear-end crashes, traffic engineers are usually willing to trade off an increase in the number of rear-end crashes for a decrease in the number of angle crashes, but if an intersection does not have an angle-crash problem, the tradeoff does not apply, and the installation of traffic signals can actually cause a deterioration in the overall safety at the intersection.

Factors to Consider when Installing a Signal

A number of factors should be considered when planning to signalize an intersection. These factors include:

- The negative effects of traffic delay. Excessive delay results in significant fuel waste, higher motorist costs, and air pollution.
- Potential diversion of arterial traffic into neighborhood streets.
- Red-light running violations and associated crashes.
- Cost. The cost for a signal ranges from $50,000 to more than $200,000 depending on the complexity of the intersection and the characteristics of the traffic using the intersection. In addition, the annual operating cost of each signal ranges from $1,000 to $5,000.

Signal Improvements That May Decrease Crashes

The following changes may decrease crashes:

- Signal retiming, phasing, and cycle improvements;
- Review and assurance of adequacy of yellow change interval/all-red clearance interval for safer travel through the intersection;
- Use of longer visors, louvers, backplates, and reflective borders;
- Installation of 12-inch signal lenses;
- Installation of additional signal heads for increased visibility;
- Provision of advance detection on the approaches so that vehicles are not in the dilemma zone when the signal turns yellow;
- Repositioning of signals to overhead (mast arm) instead of pedestal-mounted;
- Use of double red signal displays; and
- Removal of signals from late-night/early-morning programmed flash.

Introduction to the Contents of this Issue Brief

This issue brief documents estimates of the crash reduction that might be expected if a specific countermeasure or group of countermeasures is implemented with respect to traffic signals. The crash reduction estimates are presented as crash reduction factors (CRFs).

Traffic engineers and other transportation professionals can use the information contained in this issue brief when asking the following types of question: Which countermeasures might be considered at the signalized intersection of Maple and Elm streets, an intersection that is experiencing a high number of crashes? What changes in the number of crashes are possible with the various countermeasures?

Crash Reduction Factors

A CRF is the percentage crash reduction that might be expected after implementing a given countermeasure. In some cases, the CRF is negative (i.e., the implementation of a countermeasure is expected to lead to a percentage increase in crashes).

One CRF estimate is provided for each countermeasure. Where multiple CRF estimates were available from the literature, selection criteria were used to choose which CRFs to include in the issue brief:

- Firstly, CRFs from studies that took into account regression to the mean and changes in traffic volume were preferred over studies that did not.
- Secondly, CRFs from studies that provided additional information about the conditions under which the countermeasure was applied (e.g. road type, area type) were preferred over studies that did not.

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The *Desktop Reference for Countermeasures* lists all of the CRFs included in this issue brief and adds many other CRFs available in the literature. A few CRFs found in the literature were not included in the *Desktop Reference*. These CRFs were considered to have too large a range or too large a standard error to be meaningful, or the original research did not provide sufficient detail for the CRF to be useful.

A CRF should be regarded as a generic estimate of the effectiveness of a countermeasure. The estimate is a useful guide, but it remains necessary to apply engineering judgment and to consider site-specific environmental, traffic volume, traffic mix, geometric, and operational conditions that will affect the safety impact of a countermeasure. The user must ensure that a countermeasure applies to the particular conditions being considered. The reader is also encouraged to obtain and review the original source documents for more detailed information and to search databases such as the National Transportation Library (http://ntlsearch.bts.gov) for information that becomes available after the publication of this issue brief.

Presentation of the Crash Reduction Factors

In the Table presented in this issue brief, the crash reduction estimates are provided in the following format:

CRF(standard error)[REF]

The CRF is the value selected from the literature.

The use of the color blue and the italicizing of words used in the text (except for words associated with a specific document) are associated with new information provided by the Highway Safety Manual*, April 2009 draft, as listed in Reference 21 at the end of this issue brief.*

The standard error is given where available. The standard error is the standard deviation of the error in the estimate of the CRF. The true value of the CRF is unknown. The standard error provides a measure of the accuracy of estimate of the true value of the CRF. *The August 2008 edition of Issue Brief 5 used the phrase "relatively small" to indicate that a CRF is "relatively accurately known." Relatively small was not explicitly defined several years ago; however, its intention is congruent with the definition used in this edition of the Issue Brief: relatively small is defined as a CRF with a standard error ≤10. This is equivalent to the* Highway Safety Manual *AMF's (Accident Modification Factors) with standard errors of ≤0.10.*

A "relatively large" standard error *associated with a CRF is defined as >10* and indicates that the CRF is "not accurately known."

The standard error may be used to estimate a confidence interval of the true value of the CRF. (An example of a confidence interval calculation is given below.)

The [REF] is the reference number for the source information.

As an example, the CRF for the countermeasure "provide protected left-turn phase for left-turn fatal/injury crashes" is:

17*(4)*[21]

The following points should be noted:

- *The CRF of 17 means that a 17% reduction in fatal and injury crashes combined is expected after providing a protected left-turn phase.*
- This CRF is bolded which means that a) a rigorous study methodology was used to estimate the CRF, and b) *the standard error is ≤10.* A CRF which is not bolded indicates that a less rigorous methodology (e.g. a simple before-after study) was used to estimate the CRF and/ or the standard error is large compared with the CRF.
- *The standard error for this CRF is 4*. Using the standard error, it is possible to calculate the 95% confidence interval for the potential crash reduction that might be achieved by implementing the countermeasure. The 95% confidence interval is ±2 standard errors from the CRF. *Therefore, the 95% confidence interval for providing a protected left-turn phase is between 9% and 25% (17 – (2×4) = 9%, and 17 + (2×4) = 25%).*
- *The reference number is 21 (*Highway Safety Manual*, April 2009 draft, as listed in the references at the end of this issue brief).*

Using the Table

The CRFs for traffic signal-related crashes are presented in the Signalization Countermeasures Table that summarizes the available information.

Readers familiar with the previous editions of this issue brief will notice the following changes:

- Countermeasure cost estimates of low, medium, high are no longer provided, as most agencies have readily available cost estimate information with actual dollar amounts.

- Countermeasures that do not have an estimate of crash-reduction effectiveness are no longer included.

Table 1, Signalization Countermeasures is divided into three sections: signal operations countermeasures; signal hardware countermeasures; and combination signal and other countermeasures. This table is also found in Issue Brief No.8, which includes a more comprehensive toolbox of countermeasures for consideration at intersections.

The following points should be noted:

- Where available, separate CRFs are provided for different crash severities. The levels of crash severity are as follows: all, fatal/ injury, fatal, injury, or property damage only (PDO).
- Where available, existing traffic control information is provided (i.e., the conditions existing before implementation of a countermeasure). The control information is signal where the countermeasure involved a change to existing signalization. The control information is no signal or stop where the countermeasure involved a change from an unsignalized intersection to a signalized intersection.
- Where available, configuration information is provided. Two types of configuration are identified in the studies used for the CRFs: 3-leg and 4-leg.
- Where available, the table provides daily traffic volume (vehicles/day) information for the major and minor roads of the intersection where the potential effectiveness of the countermeasure was measured. Where only one volume is provided, this volume refers to the traffic volume on the major road, unless otherwise specified.
- Blank cells mean that no information is reported in the source document.
- For additional information, please visit the FHWA Office of Safety Web site (http://safety.fhwa.dot.gov).

Legend

CRF(standard error)[REF]

CRF is a crash reduction factor, which is an estimate of the percentage reduction that might be expected after implementing a given countermeasure. A number in bold indicates a rigorous study methodology and a small standard error *(≤10)* in the value of the CRF. Standard error, where available, is the standard deviation of the error in the estimate of the CRF.

[REF] is the reference number for the source information.

Additional crash types identified in the Other Crashes column:
a: Head-on
b: Run-off-road
c: Overturn
d: Night
e: Day
f: Multiple-vehicle
g: Fixed-object
h: Older-driver
i: Younger-driver
j: Right-turn
k: Pedestrian
l: Emergency vehicle

TABLE 1: SIGNALIZATION COUNTERMEASURES

Countermeasures	Crash Severity	Control	Area Type	Configuration	All Crashes	Left-Turn Crashes	Rt-Angle Crashes	Rear-end Crashes	Sideswipe Crashes	Other Crashes	Major/Minor Daily Traffic Volume (vehicles/day)
SIGNAL OPERATIONS COUNTERMEASURES											
Add all-red clearance interval (from 0 to 1 second)	All	Signal	Urban								
Add exclusive pedestrian phasing	All	Signal					0 (44) [14]			k 34 [7]	
Convert exclusive leading protected to exclusive lagging protected	All	Signal			-15(19) [6]	-49(54) [6]					
Convert permissive or permissive/protected to protected only left-turn phasing	All					99 [20]					
Convert permissive to permissive/ protected left-turn phasing	All					16 [20]					
Convert protected left-turn phase to protected/permissive	All	Signal			-20(17) [15]	-65(71) [6]		4(22) [6]			
	Fatal/Injury	Signal			-10(25) [15]						
Convert permissive to protected	*All*	*Signal*	*Urban*	*4-leg or 3-leg*	***6** (10) [21]*	***99** (1) [21]*					
Convert permissive to protected/permissive or permissive/protected phasing	*Injury*	*Signal*	*Urban*	*4-leg*		***16** (2) [21]*					*3,000-77,000/10-45,500*
Convert permissive to protected/permissive or permissive/protected phasing	*All*	*Signal*	*Urban*	*4-leg*	*1 [21]*						
Convert permissive to protected left-turn phase on multiple approaches	*All*	*Signal*		*on 1 approach*	*6 [21]*						
	All	*Signal*		*on 2 approaches*	*11 [21]*						
	All	*Signal*		*on 3 approaches*	*17 [21]*						
	All	*Signal*		*on 4 approaches*	*22 [21]*						

Countermeasures	Crash Severity	Control	Area Type	Configuration	All Crashes	Left-Turn Crashes	Rt-Angle Crashes	Rear-end Crashes	Sideswipe Crashes	Other Crashes	Major/Minor Daily Traffic Volume (vehicles/day)
SIGNAL OPERATIONS COUNTERMEASURES											
Convert permissive to protected/permissive or permissive/protected left turn phase on multiple approaches	*All*	*Signal*		*on 1 approach*	*1* [21]						
	All	*Signal*		*on 2 approaches*	*2* [21]						
	All	*Signal*		*on 3 approaches*	*3* [21]						
	All	*Signal*		*on 4 approaches*	*4* [21]						
Convert protected/permissive left-turn phase to permissive/protected	All	Signal			-13(19) [8]	33(22) [8]					
Improve signal timing [to intervals specified by the ITE Determining Vehicle Change Intervals: A Proposed Recommended Practice (1985)]	All	Signal		4-Leg	**8**(9) [15]		4(18) [15]	-12(16) [15]		h 42 [12]	
	All	Signal	All							f 5 [5]	
	All	Signal				75 [4]					
	Fatal/Injury	Signal				55 [4]	30 [4]			a 75 [4]	
	Fatal/Injury	Signal								b 62 [4]	
	Fatal/Injury	Signal		4-Leg	12 (9) [15]		-6 (22) [15]	-8 (17) [15]			
	Fatal/Injury	Signal	All							f 9 [5]	
	Fatal/Injury	Signal								k 37 [15]	
	PDO	Signal				63 [4]	46 [4]	17 [4]		b 28 [4]	
Increase yellow change interval	All	Signal			15 [4]		30 [4]				
Install emergency vehicle pre-emption systems	All									l 70 [16]	
Modify signal phasing (implement a leading pedestrian interval)	All	Signal								k 5 [7]	
Provide actuated signals	All	Signal				80 [4]	10 [4]				
Provide Advanced Dilemma Zone Detection for rural high speed approaches	Fatal/Injury	Signal	Rural	4-Leg (1 app)	39 [19]						
Provide protected left-turn phase	Fatal/Injury	Signal	Urban			***17** (4)* [21]	***25** (2)* [21]				
	All	Signal			30 [4]	41 [4]	54 [4]	27 [4]		c 27 [4]	<5,000/ lane(Total)
	All	Signal			36 [4]	46 [4]	56 [4]	35 [4]		c 35 [4]	>5,000/ lane(Total)
	All	Signal			27 [4]	48 [4]	63 [4]	31 [4]		c 31 [4]	
Provide protected/permissive left turn phase (leading green arrow)	Fatal/Injury	Signal	Urban			**17** (2) [9]	**25** (2) [9]				
Provide signal coordination	All	Signal					32 [7]				
Provide split phases	All	Signal			25 [7]						
Remove flash mode (late night/ early morning)	All	Signal			29 [7]		75 (19) [14]				
Replace existing WALK / DON'T WALK signals with pedestrian countdown signal heads	All	Signal	Urban							k 25 [10]	

Countermeasures	Crash Severity	Control	Area Type	Configuration	All Crashes	Left-Turn Crashes	Rt-Angle Crashes	Rear-end Crashes	Sideswipe Crashes	Other Crashes	Major/Minor Daily Traffic Volume (vehicles/day)
SIGNAL HARDWARE COUNTERMEASURES											
Add 3-inch yellow retroreflective sheeting to signal backplates	All	Signal	Urban		15 (51) [17]						
Add additional signal and upgrade to 12-inch lenses	All	Signal		4-Leg						h 31 [12]	
	All	Signal		4-Leg						i 17 [12]	
Add signal (additional primary head)	All	Signal	Urban	4-Leg	28 [2]		35 [2]	28 [2]			
	Fatal/Injury	Signal	Urban	4-Leg	17 [2]						
	PDO	Signal	Urban	4-Leg	31 [2]						
Convert signal from pedestal-mounted to mast arm	All	Signal			49 [16]	12 [16]	74 [16]	41 [16]			
	Fatal/Injury	Signal			44 [16]						
	PDO	Signal			51 [16]						
Improve visibility of signal heads (increase signal lens size, install new backboards, add reflective tape to existing backboards, and/or install additional signal heads)	All	Signal	Urban		7 [18]					d 6 [18]	
	All	Signal	Urban							e 6 [18]	
	Fatal/Injury	Signal	Urban		3 [18]						
	PDO	Signal	Urban		9 [18]						
Improve visibility of signal heads (install two red displays in each head)	All	Signal			9 [7]		36 [7]				
Install larger signal lenses (12 inch)	All	Signal			11 [7]		46 [14]				
	All	Signal	Urban		24 [17]						
	Fatal/Injury	Signal	Urban		16 [17]						
Install signal backplates only	All	Signal			13 [7]		50 [7]				
Install signal backplates (or visors)	All	Signal					20 [4]				
Install signals	All	No Signal			33 [7]	38 [13]				j 50 [13]	
	All	No Signal			38 [4]		74 [9]	22 [9]		c 22 [4]	<5,000/ lane(Total)
	All	No Signal			20 [4]		43 [9]	20 [9]		c 20 [4]	>5,000/ lane(Total)
	All	No Signal	Rural		15 [13]						
	All	*Stop*	*Urban*	*4-leg*	***5*** *(9)* [21]		***67*** *(6)* [21]	*-143(40)* [21]			
	All	*Stop*	*Rural*	*3-leg or 4-leg*	***44*** *(3)* [21]	***60*** *(6)* [21]	***77*** *(2)* [21]	*-58(20)* [21]			*3,300-30,000/100-10,300*
	Fatal	No Signal			38 [13]						
	Fatal/Injury	Stop	Urban	3-Leg	14 (32) [11]		34 (45) [11]	-50 (51) [11]			11,750-42,000 / 900-4000
	Fatal/Injury	Stop	Urban	4-Leg	23 (22) [11]		**67** (20) [11]	-38 (39) [11]			12,650-22,400 / 2,400-3,625
	PDO	No Signal			-15 [13]						
Install signals (temporary)	Fatal/Injury	No Signal					39 [4]		50 [4]		
	PDO	No Signal				11 [4]	73 [4]			a 83 [4]	
Install signals (to have one over each approach lane	All		All				46 [3]				

Countermeasures	Crash Severity	Control	Area Type	Configuration	All Crashes	Left-Turn Crashes	Rt-Angle Crashes	Rear-end Crashes	Sideswipe Crashes	Other Crashes	Major/Minor Daily Traffic Volume (vehicles/day)
SIGNAL HARDWARE COUNTERMEASURES											
Remove unwarranted signals	All	Signal	Urban		***24*** *(9)* [21]		***24*** *(10)* [21]	*29 (20)* [21]		d 30 [5]	
	All	Signal	Urban							e 22 [5]	
	All	Signal	Urban							g 31 [5]	
	Fatal/Injury	Signal	Urban		53 [5]						
	PDO	Signal	Urban		24 [5]						
	Pedestrian	*Signal*	*Urban*	*One-lane one-way streets excluding major arterials*	*18(30)* [21]						
Replace signal lenses with optical lenses	All	Signal			17 [7]	10 [4]	10 [4]	10 [4]		a 20 [4]	
COMBINATION SIGNAL AND OTHER COUNTERMEASURES											
Install left-turn lane and add turn phase	All	Signal			58 [7]						
Install signals and add channelization	Fatal/Injury	No Signal					67 [4]		54 [4]	b 35 [4]	
	PDO	No Signal				24 [4]	63 [4]			a 27 [4]	

Note: Any CRF with a reference of 21 is added to this version of the Intersection Safety Issue Brief 5.

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5 ISSUE BRIEFS

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FHWA-SA-10-005

Toolbox of Countermeasures and Their Potential Effectiveness for Pedestrian Crashes

Introduction

This issue brief documents estimates of the crash reduction that might be expected if a specific countermeasure or group of countermeasures is implemented with respect to pedestrian crashes. The crash reduction estimates are presented as Crash Reduction Factors (CRFs). As some studies reviewed included bicycle crashes in their analysis, some of the crash reduction estimates include bicyclists.

Traffic engineers and other transportation professionals can use the information contained in this issue brief when asking the following types of question: Which countermeasures might be considered at the signalized intersection of Maple and Elm streets, an intersection experiencing a high number of pedestrian crashes? What change in the number of pedestrian crashes can be expected with the implementation of the various countermeasures?

Crash Reduction Factors

A CRF is the percentage crash reduction that might be expected after implementing a given countermeasure. In some cases, the CRF is negative, i.e. the implementation of a countermeasure is expected to lead to a percentage increase in crashes.

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- Secondly, CRFs from studies that provided additional information about the conditions under which the countermeasure was applied (e.g. road type, area type) were preferred over studies that did not.

Where these criteria could not be met, a CRF may still be provided. In these cases, it is recognized that the reliability of the estimate of the CRF is low, but the estimate is the best available at this time. The CRFs in this issue brief may be periodically updated as new information becomes available.

The *Desktop Reference for Countermeasures* includes most of the CRFs included in this issue brief, and adds many other CRFs available in the literature. A few CRFs found in the literature were not included in the *Desktop Reference*. These CRFs were considered to have too large a range or too large a standard error to be meaningful, or the original research did not provide sufficient detail for the CRF to be useful.

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for more detailed information, and to search databases such as the National Transportation Library (ntlsearch.bts.gov) for information that becomes available after the publication of this issue brief.

Presentation of the Crash Reduction Factors

In the Tables presented in this issue brief, the crash reduction estimates are provided in the following format:

CRF(standard error)[REF]

The CRF is the value selected from the literature.

The standard error is given where available. The standard error is the standard deviation of the error in the estimate of the CRF. The true value of the CRF is unknown. The standard error provides a measure of the precision of the estimate of the true value of the CRF. A relatively small standard error indicates that a CRF is relatively precisely known. A relatively large standard error indicates that a CRF is not precisely known.

The REF is the reference number for the source information.

As an example, the CRF for the countermeasure *convert unsignalized intersection to roundabout* is:

27(12)[2]

The following points should be noted:

- The CRF of 27 means that a 27% reduction in pedestrian crashes is expected after converting the unsignalized intersection to a roundabout.
- This CRF is bolded which means that a) a rigorous study methodology was used to estimate the CRF, and b) the standard error is relatively small. A CRF which is not bolded indicates that a less rigorous methodology (e.g. a simple before-after study) was used to estimate the CRF and/or the standard error is large compared with the CRF.
- The standard error for this CRF is 12.
- The reference number is 2 (De Brabander, B. and Vereeck, L., as listed in the References at the end of this issue brief).

Using the Tables

The CRFs for pedestrian crashes are presented in three tables which summarize the available information. The Tables are:

Table 1: Signalization Countermeasures

Table 2: Geometric Countermeasures

Table 3: Signs/Markings/Operational Countermeasures

The following points should be noted:

- Where available, separate CRFs are provided for different crash severities. The crash severities are: all, fatal/injury, fatal, or injury. The categories depend on the approach taken by the original study. For example, some studies referred to fatal/injury (fatal and injury crashes combined). Some distinguished fatal from injury. "All" is used for CRFs from studies which did not specify the severity. "All" is also used for CRFs that refer to the total number of crashes, including pedestrians.
- The CRF listed under the pedestrian column refers to the reduction in crashes involving pedestrians crossing the street, unless otherwise specified.
- Blank cells mean that no information is reported in the source document.
- For additional information, please visit the FHWA Office of Safety website (safety.fhwa.dot.gov).

Legend

CRF(standard error)REF

CRF is a crash reduction factor, which is an estimate of the percentage reduction that might be expected after implementing a given countermeasure. A number in bold indicates a rigorous study methodology and a small standard error in the value of the CRF. Standard error, where available, is the standard deviation of the error in the estimate of the CRF.
REF is the reference number for the source information.

Table 1: Signalization Countermeasures

Countermeasure(s)	Crash Severity	Left-Turn Crashes	Pedestrian
Add exclusive pedestrian phasing	All		34[4]
Improve signal timing [to intervals specified by the ITE *Determining Vehicle Change Intervals: A Proposed Recommended Practice (1985)*]	Fatal/Injury		37[8]
Replace existing WALK / DON'T WALK signals with pedestrian countdown signal heads	All		25[5]
Modify signal phasing (implement a leading pedestrian interval)	All		5[4]
Remove unwarranted signals (one-way street)	All		17[7]
Convert permissive or permissive/protected to protected only left-turn phasing	All	99[10]	
Convert permissive to permissive/protected left-turn phasing	All	16[10]	

Table 2: Geometric Countermeasures

Countermeasure(s)	Crash Severity	All Crashes	Pedestrian
Convert unsignalized intersection to roundabout	Fatal/Injury		**27**(12)[2]
Install pedestrian overpass/underpass	Fatal/Injury		90[3]
	All		86[3]
Install pedestrian overpass/underpass (unsignalized intersection)	All		13[4]
Install raised median	All		25[3]
Install raised median (marked crosswalk) at unsignalized intersection	All		46[9]
Install raised median (unmarked crosswalk) at unsignalized intersection	All		39[9]
Install raised pedestrian crossing	All	30(67)[1]	
	Fatal/Injury	36(54)[1]	
Install refuge islands	All		56[4]
Install sidewalk (to avoid walking along roadway)	All		88[6] *
Provide paved shoulder (of at least 4 feet)	All		71[3] *
Narrow roadway cross section from four lanes to three lanes (two through lanes with center turn lane)	All	29[10]	

*** This only applies to "walking along the roadway" type crashes**

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Table 3: Signs/Markings/Operational Countermeasures

Countermeasure(s)	Crash Severity	All Crashes	Pedestrian
Add intersection lighting	Injury	27[10] *	
	All	21[10] *	
Add segment lighting	Injury	23[10] *	
	All	20[10] *	
Improve pavement friction (skid treatment with overlay)	Fatal/Injury		3[3]
Increase enforcement **	All		23[11]
Prohibit right-turn-on-red	All	3[10]	
Prohibit left-turns	All		10[3]
Restrict parking near intersections (to off-street)	All		30[3]

*** This applies to nighttime crashes only**

**** This applies to crash reduction on corridors where sustained enforcement is used related to motorist yielding in marked crosswalks combined with a public education campaign**

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