Countermeasures for Intersection Crashes

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Credit: 1 PDH

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8 ISSUE BRIEFS

Toolbox of Countermeasures and Their Potential Effectiveness for Intersection 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 intersection crashes. 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 experiencing a high number of total crashes and left-turn crashes? What change in the number of total crashes and left-turn 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).

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.

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* 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.

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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 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 43 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 8 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 "install cameras to detect red-light running" for right-angle fatal/injury crashes is:

16(6)[27]

The following points should be noted:

- The CRF of 16 means that a 16% reduction in right-angle fatal/injury crashes is expected after the installation of red-light running cameras.
- 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 6. 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 the installation of red-light running cameras for right-angle fatal/injury crashes is between 4% and 28% (16 - 2×6 = 4%, and 16 + 2×6 = 28%).
- The reference number is 27 (Persaud et al., as listed in the references at the end of this issue brief).

Using the Tables

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

Table 1
Signalization Countermeasures, which includes signal operations countermeasures, signal hardware countermeasures,
and combination signal and other countermeasures

Table 2
Geometric Countermeasures, which includes left turn countermeasures, right turn countermeasures, and other geometric countermeasures

Table 3
Signs/Markings/Operational Countermeasures, which includes signs, pavement markings modifications, regulatory, lighting, and operational countermeasures

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.

The following points should be noted:

- Where available, separate CRFs are provided for different crash severities. The crash severities 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 may be no signal, signal, stop, or stop/ yield. "Undefined" is used when a publication does not provide more specific information such as no signal, signal, stop, or yield controlled.
- Where available, the Tables provide 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: Speed-related
l: Speed related/day
m: Speed related/night
n: Speed related/dry
o: Speed related/wet
p: Wet
q: Night/wet
r: Pedestrian
s: All turns
t: Bicycle
u: Emergency vehicle
rt. Pedestrian and bicycle

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) [28]			r 34 [16]	
Convert exclusive leading protected to exclusive lagging protected	All	Signal			-15(19) [15]	-49(54) [15]					
Convert permissive or permissive/protected to protected only left-turn phasing	All					99 [41]					
Convert permissive to permissive/ protected left-turn phasing	All					16 [41]					
Convert protected left-turn phase to protected/permissive	All	Signal			-20(17) [15]	-65(71) [15]		4(22) [15]			
	Fatal/Injury	Signal			-10(25) [6]						
Convert permissive to protected	*All*	*Signal*	*Urban*	*4-leg or 3-leg*	***6** (10) [43]*	***99** (1) [43]*					
Convert permissive to protected/permissive or permissive/protected phasing	*Injury*	*Signal*	*Urban*	*4-leg*		***16** (2) [43]*					*3,000-77,000/10-45,500*
Convert permissive to protected/permissive or permissive/protected phasing	*All*	*Signal*	*Urban*	*4-leg*	*1 [43]*						
Convert permissive to protected left-turn phase on multiple approaches	*All*	*Signal*		*on 1 approach*	*6 [43]*						
	All	*Signal*		*on 2 approaches*	*11 [43]*						
	All	*Signal*		*on 3 approaches*	*17 [43]*						
	All	*Signal*		*on 4 approaches*	*22 [43]*						
Convert permissive to protected/permissive or permissive/protected left turn phase on multiple approaches	*All*	*Signal*		*on 1 approach*	*1 [43]*						
	All	*Signal*		*on 2 approaches*	*2 [43]*						
	All	*Signal*		*on 3 approaches*	*3 [43]*						
	All	*Signal*		*on 4 approaches*	*4 [43]*						
Convert protected/permissive left-turn phase to permissive/protected	All	Signal			-13(19) [17]	33(22) [17]					
Improve signal timing [to intervals specified by the ITE Determining Vehicle Change Intervals: A Proposed Recommended Practice (1985)]	All	Signal		4-Leg	**8**(9) [30]		4(18) [30]	-12(16) [30]		h 42 [25]	
	All	Signal	All							f 5 [11]	
	All	Signal				75 [9]					
	Fatal/Injury	Signal				55 [9]	30 [9]			a 75 [9]	
	Fatal/Injury	Signal								b 62 [9]	
	Fatal/Injury	Signal		4-Leg	12 (9) [30]		-6 (22) [30]	-8 (17) [30]			
	Fatal/Injury	Signal	All							f 9 [11]	
	Fatal/Injury	Signal								r 37 [30]	
	PDO	Signal				63 [9]	46 [9]	17 [9]		b 28 [9]	
Increase yellow change interval	All	Signal			15 [9]		30 [9]				

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											
Install emergency vehicle pre-emption systems	All									u 70 [31]	
Modify signal phasing (implement a leading pedestrian interval)	All	Signal								r 5 [16]	
Provide actuated signals	All	Signal				80 [9]	10 [9]				
Provide Advanced Dilemma Zone Detection for rural high speed approaches	Fatal/Injury	Signal	Rural	4-Leg (1 app)	39 [40]						
Provide protected left-turn phase	Fatal/Injury	Signal	Urban			***17*** *(4)* [43]	***25*** *(2)* [43]				
	All	Signal			30 [9]	41 [9]	54 [9]	27 [9]		c 27 [9]	<5,000/ lane(Total)
	All	Signal			36 [9]	46 [9]	56 [9]	35 [9]		c 35 [9]	>5,000/ lane(Total)
	All	Signal			27 [9]	48 [9]	63 [9]	31 [9]		c 31 [9]	
Provide protected/permissive left turn phase (leading green arrow)	Fatal/Injury	Signal	Urban			**17** (2) [19]	**25** (2) [19]				
Provide signal coordination	All	Signal					32 [16]				
Provide split phases	All	Signal			25 [16]						
Remove flash mode (late night/ early morning)	All	Signal			29 [16]		75 (19) [28]				
Replace existing WALK / DON'T WALK signals with pedestrian countdown signal heads	All	Signal	Urban							r 25 [20]	
SIGNAL HARDWARE COUNTERMEASURES											
Add 3-inch yellow retroreflective sheeting to signal backplates	All	Signal	Urban		15 (51) [33]						
Add additional signal and upgrade to 12-inch lenses	All	Signal		4-Leg						h 31 [25]	
	All	Signal		4-Leg						i 17 [25]	
Add signal (additional primary head)	All	Signal	Urban	4-Leg	28 [7]		35 [7]	28 [7]			
	Fatal/Injury	Signal	Urban	4-Leg	17 [7]						
	PDO	Signal	Urban	4-Leg	31 [7]						
Convert signal from pedestal-mounted to mast arm	All	Signal			49 [31]	12 [31]	74 [31]	41 [31]			
	Fatal/Injury	Signal			44 [31]						
	PDO	Signal			51 [31]						
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 [35]					d 6 [35]	
	All	Signal	Urban							e 6 [35]	
	Fatal/Injury	Signal	Urban		3 [35]						
	PDO	Signal	Urban		9 [18]						
Improve visibility of signal heads (install two red displays in each head)	All	Signal			9 [16]		36 [16]				
Install larger signal lenses (12 inch)	All	Signal			11 [16]		46 [28]				
	All	Signal	Urban		24 [33]						
	Fatal/Injury	Signal	Urban		16 [33]						
Install signal backplates only	All	Signal			13 [16]		50 [16]				
Install signal backplates (or visors)	All	Signal					20 [9]				

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											
Install signals	All	No Signal			33 [16]	38 [26]				j 50 [26]	
	All	No Signal			38 [9]		74 [9]	22 [9]		c 22 [9]	<5,000/ lane(Total)
	All	No Signal			20 [9]		43 [9]	20 [9]		c 20 [9]	>5,000/ lane(Total)
	All	No Signal	Rural		15 [26]						
	All	*Stop*	*Urban*	*4-Leg*	***5** (9)* [43]		***67** (6)* [43]	*-143(40)* [43]			
	All	*Stop*	*Rural*	*3-leg or 4-leg*	***44** (3)* [43]	***60** (6)* [43]	***77** (2)* [43]	*-58(20)* [43]			*3,300-30,000/100-10,300*
	Fatal	No Signal			38 [26]						
	Fatal/Injury	Stop	Urban	3-Leg	14 (32) [21]		34 (45) [21]	-50 (51) [21]			11,750-42,000 / 900-4000
	Fatal/Injury	Stop	Urban	4-Leg	23 (22) [21]		**67** (20) [21]	-38 (39) [21]			12,650-22,400 / 2,400-3,625
	PDO	No Signal			-15 [26]						
Install signals (temporary)	Fatal/Injury	No Signal					39 [9]		50 [4]		
	PDO	No Signal				11 [9]	73 [9]			a 83 [9]	
Install signals (to have one over each approach lane	All		All				46 [8]				
Remove unwarranted signals	All	Signal	Urban		***24** (9)* [43]		***24** (10)* [43]	*29 (20)* [43]		d 30 [11]	
	All	Signal	Urban							e 22 [11]	
	All	Signal	Urban							g 31 [11]	
	Fatal/Injury	Signal	Urban		53 [11]						
	PDO	Signal	Urban		24 [11]						
	Pedestrian	*Signal*	*Urban*	*One-lane one-way streets excluding major arterials*	*18(30)* [43]						
Replace signal lenses with optical lenses	All	Signal			17 [16]	10 [9]	10 [9]	10 [9]		a 20 [9]	
COMBINATION SIGNAL AND OTHER COUNTERMEASURES											
Install left-turn lane and add turn phase	All	Signal			58 [16]						
Install signals and add channelization	PDO	No Signal				24 [9]	63 [9]			a 27 [9]	
	Fatal/Injury	No Signal					67 [9]		54 [9]	b 35 [9]	

TABLE 2: GEOMETRIC 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)
LEFT TURN COUNTERMEASURES											
	All	Stop			18 (8) [38]						>34,000
	All	Stop			-24 (35) [38]						>34,000/4 lanes
	All	Stop			26 (8) [38]						>34,000/6 lanes
	All	Stop			24 (63) [38]						>34,000/8 lanes
	Fatal/Injury	Stop			27 (12) [38]						>34,000
	PDO	Stop			6 (11) [38]						>34,000
Create directional median openings to allow left turns and u-turns	All	Signal			51 [31]						
Install left-turn lane	All	Signal	Rural	3-Leg	15 [14]						4,200-26,000/ 1,300-11,400
	All	Signal	Rural	4-Leg (1 app)	18 [14]						4,200-26,000/ 1,300-11,400
	All	*Signal*	*Rural*	*4-leg (2 app)*	*33* [43]						
	All	Signal	Urban	3-Leg	7 [14]						4,600-55,100/ 100-26,000
	All	Signal	Urban	4-Leg (1 app)	**10** (10) [43]	13 [11]					*7,200-55,100/ 350-2,600*
	All	Signal	Urban	4-Leg (2 apps)	**19** *(10)* [43]	24 [11]					*7,200-55,100/ 350-2,600*
	All	Stop	Rural	3-Leg	**44** (6) [43]	62 [11]					*1,600-32,400/ 50-11,800*
	All	Stop	Rural	4-Leg (1 app)	**28** (3) [43]	37 [11]					*1,600-32,400/ 50-11,800*
	All	Stop	Rural	4-Leg (2 apps)	**48** (3) [43]	60 [11]					*1,600-32,400/ 50-11,800*
	All	Stop	Urban	3-Leg	*33 (20)* [43]						1,520-40,600/ *200-* 8,000
	All	Stop	Urban	4-Leg (1 app)	**27** (3) [43]	26 [11]					1,520-40,600/ *200-* 8,000
	All	Stop	Urban	4-Leg (2 apps)	**47** (4) [43]	45 [11]					1,520-40,600/ *200-* 8,000
	Fatal/Injury	*Signal*	*Urban*	*3-Leg ; on 1 major road app.*	*6* [43]						
	Fatal/Injury	Signal	Urban	4-Leg (1 app)	**9** *(2)* [43]						*7,200-55,100/ 350-2,600*
	Fatal/Injury	Signal	Urban	4-Leg (2 apps)	**17** (2) [43]						*7,200-55,100/ 350-2,600*
	Fatal/Injury	Stop	Rural	3-Leg	**55** *(10)* [43]						*1,600-32,400/ 50-11,800*
	Fatal/Injury	Stop	Rural	4-Leg (1 app)	**35** (3) [43]						*1,600-32,400/ 50-11,800*
	Fatal/Injury	Stop	Rural	4-Leg (2 apps)	**58** (4) [43]						*1,600-32,400/ 50-11,800*
	Fatal/Injury	*Stop*	*Urban*	*3-Leg ; on 1 major road app.*	*35* [43]						

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)
LEFT TURN COUNTERMEASURES											
	Fatal/Injury	Stop	Urban	4-Leg (1 app)	**29** (4) [43]						1,520-40,600/ *200-* 8,000
	Fatal/Injury	Stop	Urban	4-Leg (2 apps)	**50** (6) [43]						1,520-40,600/ *200-* 8,000
Install left turn lane on newly signalized intersection	*All*	*Newly Signalized*	*Urban*	*4-leg (1 approach)*	***24*** *(3)* [43]						*4,600 to 40,300/100 to 13,700*
	Fatal/Injury	*Newly Signalized*	*Urban*	*4-leg (1 approach)*	***28*** *(6)* [43]						*4,600 to 40,300/100 to 13,700*
	All	*Newly Signalized*	*Urban*	*4-leg (2 approach)*	***42*** *(4)* [43]						*4,600 to 40,300/100 to 13,700*
	Fatal/Injury	*Newly Signalized*	*Urban*	*4-leg (2 approach)*	***48*** *(7)* [43]						*4,600 to 40,300/100 to 13,700*
Install left-turn lane (double)	Fatal/Injury	Undefined				47 [9]	20 [9]	29 [9]	50 [9]	a 75 [9]	
	PDO	Undefined				71 [9]	8 [9]	32 [9]		b 13 [9]	
Install left-turn lane painted separation	All	Undefined			50 [9]	57 [9]	62 [9]	54 [9]		c 54 [9]	<5,000/lane (Total)
	All	Undefined				35 [9]	49 [9]	39 [9]		c 39 [9]	>5,000/lane (Total)
	Fatal/Injury	Undefined	Mostly rural	3-Leg	22 (14) [6]						5,000-15,000
	Fatal/Injury	Undefined	Mostly rural	4-Leg	-28 (27) [6]						5,000-15,000
	PDO	Undefined	Mostly rural	3-Leg	20 (19) [6]						5,000-15,000
	PDO	Undefined	Mostly rural	4-Leg	26 (12) [6]						5,000-15,000
Install left-turn lane (physical channelization)	All	No Signal		4-Leg (2 apps)	42 [16]						
	All	No Signal	Rural	3-Leg	44 [16]						
	All	No Signal	Rural	4-Leg (1 app)	28 [16]						
	All	No Signal	Urban	3-Leg	33 [16]						
	All	No Signal	Urban	4-Leg (1 app)	27 [16]						
	All	Undefined			51 [9]	24 [9]	68 [9]	50 [9]		c 50 [9]	<5,000/lane (Total)
	All	Undefined			19 [9]	24 [9]	55 [9]	28 [9]		c 28 [9]	>5,000/lane (Total)
	Fatal/Injury	Undefined				50 [9]	58 [9]	11 [9]			
	Fatal/Injury	Undefined	Rural	4-Leg (major road approaches)	4 *(20)* [43]						5,000-15,000
	Fatal/Injury	*Signalized, minor road stop controlled, and all way stop controlled*	*Rural*	*4-leg (all approaches)*	***27****(10)* [43]						*5,000 to 15,000*
	Fatal/Injury	*Signalized, minor road stop controlled, and all way stop controlled*	*Rural*	*3-leg (1 app)*	*27(20)* [43]						*5,000 to 15,000*
	Fatal/Injury	*Signalized, minor road stop controlled, and all way*	*Rural*	*3-leg (2 app)*	*-16(20)* [43]						*5,000 to 15,000*
	PDO	Undefined					54 [9]	56 [9]		b 50 [9]	
	PDO	Undefined	Rural	3-Leg	-20 (23) [6]						5,000-15,000
	PDO	Undefined	Rural	4-Leg	16 (22) [6]						5,000-15,000

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)
LEFT TURN COUNTERMEASURES											
Install left-turn lane (signal has left-turn phase)	All	Signal			31 [16]	44 [16]					
	All	Signal		4-Leg						h 73 [25]	
	All	Signal		4-Leg						i 66 [25]	
Install left-turn lane (signal has no turn phase	All	Signal			23 [16]	50 [16]					
Install left-turn lane (with channelization and existing left-turn phase)	All	Signal			35 [9]						
Install left-turn lane (with channelization and no left-turn phase)	All	Undefined			15 [9]						
Install left-turn lane within existing curbs	All	Signal			26 [16]	66 [16]					
Install left-turn refuge within flush median	All	Undefined			24 [9]			44 [9]		c 44 [9]	<5,000/lane (Total)
	All	Undefined			44 [9]	77 [9]		40 [9]	52 [9]	a 52 [9]	>5,000/lane (Total)
	All	Undefined								c 40 [9]	>5,000/lane (Total)
Remove left-turn lane	All	Signal	Rural	3-Leg	-18 [3]						
	All	Signal	Rural	4-Leg (1 app)	-22 [3]						
	All	Signal	Rural	4-Leg (2 apps)	-49 [3]						
	All	Signal	Urban	3-Leg	-8 [3]						
	All	Signal	Urban	4-Leg (1 app)	-11 [3]						
	All	Signal	Urban	4-Leg (2 apps)	-23 [3]						
	All	Stop	Urban	3-Leg	-49 [3]						
	All	Stop	Urban	4-Leg (1 app)	-37 [3]						
	All	Stop	Urban	4-Leg (2 apps)	-88 [3]						
	Fatal/Injury	Signal	Rural	3-Leg	-16 [3]						
	Fatal/Injury	Signal	Rural	4-Leg (1 app)	-21 [3]						
	Fatal/Injury	Signal	Rural	4-Leg (2 apps)	-45 [3]						
	Fatal/Injury	Signal	Urban	3-Leg	-6 [3]						
	Fatal/Injury	Signal	Urban	4-Leg (1 app)	-10 [3]						
	Fatal/Injury	Signal	Urban	4-Leg (2 apps)	-21 [3]						
	Fatal/Injury	Stop	Urban	3-Leg	-53 [3]						
	Fatal/Injury	Stop	Urban	4-Leg (1 app)	-41 [3]						
	Fatal/Injury	Stop	Urban	4-Leg (2 apps)	-98 [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)
RIGHT TURN COUNTERMEASURES											
Increase length of right-turn lane	Fatal/Injury	All	All	All	15 [37]						
Install right-turn lane	All	Signal	All	4-Leg *or 3 leg (1 app)*	**4** (2) [43]						*7,200-55,100 / 550-26,000*
	All	Stop	All	4-Leg (1 app)	**14** (5) [43]						*1,520-40,600 / 25-26,000*
	All	Signal	All	4-Leg (2 apps)	**8**(3) [43]						*7,200-55,100 / 550-26,000*
	All	Stop	All	4-Leg (2 apps)	**26**(7) [43]						*1,520-40,600 / 25-26,000*
	Fatal/Injury	Signal	All	4-Leg *or 3 leg (1 app)*	**9**(3) [43]						*7,200-55,100 / 550-26,000*
	Fatal/Injury	Stop	All	4-Leg *or 3 leg (1 app)*	**23**(7) [43]						*1,520-40,600 / 25-26,000*
	All	Undefined					50 [9]	65 [9]	20 [9]	j 53 [9]	
Provide a right-turn lane on both major road approaches	*Fatal/Injury*	*Stop*	*All*	*4-leg*	*41* [43]						
	Fatal/Injury	*Signal*	*All*	*4-leg*	*17* [43]						
Install right turn lane (painted separation)	Fatal/Injury	All	All	All	30 [37]						
Install left-turn lane (physical channelization)	Fatal/Injury	All	All	All	35 [37]						
OTHER GEOMETRIC COUNTERMEASURES											
Convert four-leg to two T-intersections	Fatal/Injury	Undefined	Urban	4-Leg	**33** *(10)* [43]						<70%/>30%
	Fatal/Injury	Undefined	Urban	4-Leg	-35 *(30)* [43]						>85%/<15%
	Fatal/Injury	Undefined	Urban	4-Leg	**25** *(8)* [43]						70-85%/15-30%
	PDO	Undefined	Urban	4-Leg	**10** *(9)* [43]						<70%/>30%
	PDO	Undefined	Urban	4-Leg	**-15** *(10)* [43]						>85%/<15%
	PDO	*Undefined*	*Urban*	*4-Leg*	***0*** *(9)* [43]						70-85%/15-30%

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)
OTHER GEOMETRIC COUNTERMEASURES											
Convert intersection to roundabout	All	All	All		**35** (3) [32]						
	All	Signal	All		**48** (5) [43]						
	All	Stop (2-way)	All		**44** (4) [43]						
	All	Stop (4-way)	All		-3 (15) [32]						
	All	Stop (2-way)	Rural	1-Lane	***71*** (4) [43]						
	All	Signal	Urban		1 (12) [32]						
	All	Stop (2-way)	Urban		***29*** *(10)* [43]						
	All	Stop (2-way)	Urban	1-Lane	***39*** *(10)* [43]						
	All	Signal	Urban	2-Lanes	**67** (4) [32]						
	All	Stop (2-way)	Urban	2-Lanes	*12 (20)* [43]						
	Fatal/Injury	All	All		**76** (3) [32]						
	Fatal/Injury	Signal	All		**78** (6) [32]						
	Fatal/Injury	Stop (2-way)	All		**82** (3) [43]						
	Fatal/Injury	Stop (4-way)	All		-28 (41) [32]						
	Fatal/Injury	Stop (2-way)	Rural	1-Lane	**87** (3) [32]						
	Fatal/Injury	Signal	Urban		**60** (12) [32]						
	Fatal/Injury	Stop (2-way)	Urban		***81*** *(10)* [43]						
	Fatal/Injury	Stop (2-way)	Urban	1-Lane	**78** (7) [32]						
	Fatal/Injury	Stop (2-way)	Urban	2-Lanes	**72** (9) [32]						
	All	*Stop (2-way)*	*Suburban*		***32*** *(8)* [43]						
	All	*Stop (2-way)*	*Suburban*	*1-lane*	***78*** *(7)* [43]						
	All	*Stop (2-way)*	*Suburban*	*2-lane*	***19*** *(10)* [43]						
	Fatal/Injury	*Stop (2-way)*	*Suburban*		***71*** *(10)* [43]						
	Fatal/Injury	*Stop (2-way)*	*Suburban*	*1-lane*	***78*** *(10)* [43]						
	Fatal/Injury	*Stop (2-way)*	*Suburban*	*2-lane*	***68*** *(10)* [43]						
Improve sight distance in 1 quadrant	All	Stop/Yield (2-way)	Rural	4-Leg	5 [13]						
Improve sight distance in 2 quadrants	All	Stop/Yield (2-way)	Rural	4-Leg	9 [13]						
Improve sight distance in 3 quadrants	All	Stop/Yield (2-way)	Rural	4-Leg	13 [13]						
Improve sight distance in 4 quadrants	All	Stop/Yield (2-way)	Rural	4-Leg	17 [13]						
	All	Signal	Rural	4-Leg	0 [13]						
Increase median width by 3-feet	All	Stop	Rural	4-Leg						**f 4** (1) [12]	
	All	Stop	Urban	3-Leg						**f -3** (1) [12]	
	All	Signal	Urban	4-Leg						**f -3** (1) [12]	
	All	Stop	Urban	4-Leg						**f -6** (1) [43]	
	Fatal/Injury	Stop	Rural	4-Leg						**f 4** *(2)* [43]	
	Fatal/Injury	Signal	Urban	4-Leg						**f -3** (1) [43]	
	Fatal/Injury	Stop	Urban	4-Leg						**f -5** *(2)* [43]	
Increase pedestrian storage area at corner	Fatal/Injury	Undefined			-12 (126) [2]						

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)
OTHER GEOMETRIC COUNTERMEASURES											
Install median	All	Stop	Rural		27 [3]						
Install median islands (painted) on major road approaches	Fatal/Injury	All	All	All	15 [37]						
Install median islands (physical) on major road approaches	Fatal/Injury	All	All	All	25 [37]						
Install raised median	All	No Signal			25 [16]						
Install raised median (marked crosswalk)	All	No Signal								r 46 [38]	
Install raised median (unmarked crosswalk)	All	No Signal								r 39 [38]	
Install refuge islands	All	Undefined								r 56 [16]	
Install splitter islands on minor road approaches	Fatal/Injury	All	All	3-Leg	45 [37]						
	Fatal/Injury	All	All	4-Leg	40 [37]						
	Fatal/Injury	All	All	All	40 [37]						
	Fatal/Injury	All	Rural	All	35 [37]						
	Fatal/Injury	All	Urban	All	40 [37]						
Install turn and bypass lanes	All	Stop	Rural		5 (10) [29]						
	Injury	Undefined		3-Leg		36 [9]	24 [9]	18 [9]			
	PDO	Undefined		3-Leg		28 [9]	53 [9]	21 [9]	30 [9]	a 13 [9]	
	PDO	Undefined		3-Leg						b 40 [9]	

TABLE 3: SIGNS/MARKINGS/OPERATIONAL 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)
SIGNS											
Install double stop signs	All	No Signal			11 [16]		55 (52) [28]				
Install flashing beacons as advance warning	All	Undefined		3-Leg	70 [9]						
	All	Undefined		4-Leg	39 [9]						
	All	Signal			27 [16]						
	Fatal/Injury	Undefined				67 [9]	73 [9]				
	PDO	Undefined				79 [9]	62 [9]				
	All	Signal		4-Leg			62 [25]	36 [25]			
Install flashing beacons at stop controlled intersections	*All*	*Stop*	*All*	*Four-leg*	***5*** *(4)* [43]						
	Injury	*Stop*	*All*	*Four-leg*	***10*** *(6)* [43]						
	All	*Stop*	*All*	*Four-leg*				***8****(10)* [43]			
	All	*Stop*	*All*	*Four-leg*			***13****(6)* [43]				
	All	*Stop*	*Rural*	*Four-leg*			***16****(6)* [43]				
	All	*Stop*	*Suburban*	*Four-leg*			***12****(10)* [43]				
	All	*Stop*	*Urban*	*Four-leg*			*-12(30)* [43]				
	All	*Stop (2-way)*	*All*	*Four-leg*			***13****(6)* [43]				
	All	*Stop (4-way)*	*All*	*Four-leg*			*28(20)* [43]				
	All	*Standard Overhead Beacon*	*All*	*Four-leg*			***12****(6)* [43]				
	All	*Standard Mounted Beacon*	*All*	*Four-leg*			*58(20)* [43]				
	All	*Standard Overhead and Stop Mounted Beacon*	*All*	*Four-leg*			***13****(6)* [43]				
	All	*Actuated Beacon*	*All*	*Four-leg*			***14****(10)* [43]				
Install larger stop signs	All	Stop			19 [9]						>5,000/lane (Total)
Install pedestrian signing	All	Undefined			4 [9]						
	All	Undefined								r 15 [9]	
Install advance warning signs (positive guidance)	All	Signal			22 [16]		**35** (1) [28]				
	All	Undefined	Urban		30 [9]						
	All	Undefined	Rural		40 [9]						
Provide overhead lane-use signs	All	Undefined			10 [31]						
	All	Undefined			20 [31]						
PAVEMENT MARKINGS/MODIFICATIONS											
Add centerline and move STOP bar to extended curb lines	All	No Signal			29 [16]		24 [16]				
Add centerline and move STOP bar to extended curb lines; double stop signs	All	No Signal			9 [16]		0 [16]				
Add centerline and STOP bar, replace 24-inch with 30-inch stop signs	All	No Signal					67 (11) [28]				
Improve pavement friction (groove)	All	Undefined			25 [16]					p 59 [16]	
Improve/install pedestrian crossing	All	Undefined								r 25 [9]	
Install pedestrian crossing	Fatal/Injury	Undefined	Rural							r 60 [24]	
Install pedestrian crossing (raised)	All	Undefined			30 (67) [2]						
	Fatal/Injury	Undefined			36 (54) [2]						
Install raised intersection	Fatal/Injury	Undefined		4-Leg	-5 [6]						
	PDO	Undefined		4-Leg	-13 [6]						

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)
PAVEMENT MARKINGS/MODIFICATIONS											
Install raised pavement markers	All	Undefined			10 [16]					p 25 [16]	
	All	Undefined								q 33 [16]	
Install STOP bars (pedestrian crosswalk)	All	Signal			18 [16]						
Install STOP bars (STOP bar on minor road approaches with short segments of centerline	All	Undefined			19 [16]						
	All	Undefined					47 [16]				
Install transverse pavement markings	All	Undefined			18 [9]						
	Fatal/Injury	Stop								k 57(8) [10]	
	Serious Injury	Stop								k 74(13) [10]	
	Slight Injury	Stop								k 52(11) [10]	
	All	Stop								l 66(8) [10]	
	All	Stop								k 48(14) [10]	
	All	Stop								n 45(15) [10]	
	All	Stop								o 68(11) [10]	
Install Stop-Ahead Pavement Markings	*All*	*Stop*	*Rural*				*-4(30)* [43]				
	All	*Stop*	*Rural*					*29(30)* [43]			
	Injury	*Stop*	*Rural*		*22(20)* [43]						
	All	*Stop*	*Rural*		***31*** *(10)* [43]						
	Injury	*Stop*	*Rural*	*3-leg*	*55(30)* [43]						
	All	*Stop*	*Rural*	*3-leg*	*60(20)* [43]						
	Injury	*Stop*	*Rural*	*4-leg*	*12(30)* [43]						
	All	*Stop*	*Rural*	*4-leg*	*23(20)* [43]						
	Injury	*Stop (all-way)*	*Rural*		*42(30)* [43]						
	All	*Stop (all-way)*	*Rural*		*56(20)* [43]						
	Injury	*Minor Road stop controlled*	*Rural*		*8(30)* [43]						
	All	*Minor Road stop controlled*	*Rural*		*13(20)* [43]						
Install transverse rumble strips on approaches	All	Stop			28 [9]						
	All	Undefined						90 [9]			
	All	No Signal	Rural		35 [16]						
Mark pavement with supplementary warning messages	All	No Signal			6 [16]						
	Stop	Urban				30 (66) [28]					
(advance stop bar to leave dedicated space for cyclists	All	Signal								t 35 [31]	
Provide bicycle lanes	All	Undefined								t 36 [31]	
Resurface pavement	All	Undefined			33 [16]					p 47 [16]	
REGULATORY											
Convert STOP control to Yield control	All	Stop	Urban	4-Leg	-127 (70) [22]						
	All	Stop	All		-137 [11]						
Convert to all-way STOP control (from two-way STOP control)	Fatal/Injury	Stop	Urban		***70*** *(6)* [43]						
	All	Stop	Urban			20 (52) [18]	*75* (3) [43]	*18 (10)* [43]		*r 43(20)* [43]	
	All	*Stop*	*Rural*		***48*** *(4)* [43]						
Convert two-way to one-way roadway	All	Undefined			26 [9]						
Convert Yield control to STOP control	All	No Signal			29 [16]		9 [16]				

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)
REGULATORY											
Install no left-turn and no u-turn signs	All	Undefined	Urban *and Suburban*		*72 (20)* [43]	*77 (20)* [43]					19,435-42,000 (Total)
Permit right-turn-on-red	All	Signal			**-7** (1) [2]					r -43(24) [2]	
	All	*Signal*								*rt **-69** (10)* [43]	
	All	*Signal*								*r -57(20)* [43]	
	All	*Signal*								*t -80(20)* [43]	
	Fatal/Injury	Signal								j -60 (5) [6]	
	PDO	Signal								j -10 (1) [6]	
Prohibit left turns	All	Undefined			45 [9]	90 [9]		30 [9]		r 10 [9]	
Prohibit left-turns with "No Left Turn Sign"	*All*	*Undefined*	*Urban and Suburban*	*3-leg and 4-leg*	***68** (10)* [43]	*64(20)* [43]					*19,435 - 42,000*
Prohibit right-turn-on-red	All	Signal			3 [41]		30 [9]	20 [9]	20 [9]	b 30 [9]	
Prohibit turns	All	Undefined	All							s 45 [1]	
Restrict parking near intersections to off-street	All	Undefined			49 [16]					r 30 [9]	
LIGHTING											
Install lighting	All	Signal			30 [31]					d 50 [31]	
	Fatal/Injury	Signal			17 [31]						
	All	No Signal			47 [16]						
	Injury		*All*		***38**(10)* [43]						
	Injury		*All*							*r 42(20)* [43]	
OPERATIONAL											
Convert STOP control (2-way) to signal control	All	Stop			28 [9]		74 [9]				
	Injury	Stop			43 [9]						
Convert STOP control (2-way) to signal control and install left-turn lane	All	Stop			36 [9]		74 [9]	8 [9]			
	Injury	Stop			53 [9]						
Increase enforcement related to motorist yielding in marked crosswalks combined with a public education campaign	All	Undefined								r 23 [42]	
Install angled median crosswalk	All	Undefined			12 [16]						
Install beacon (flashing) at intersection	All	Undefined	All		30 [1]						
Install cameras to detect red-light running	All	Signal	Urban				***26*** (3) [43]	***-18*** (3) [43]			
	All	Signal			**-12** (5) [23]						17,000-78,000
	All	Signal	Urban			**45** (6) [36]					
	Fatal/Injury	Signal			-14 (9) [23]						17,000-78,000
	Fatal/Injury	Signal					**16** (6) [27]	***-24** (10)* [43]			
Install flashing red/yellow signal (MUTCD: intersection control beacon)	All	No Signal			25 [9]		35 [9]				<5,000/lane (Total)
	All	No Signal			26 [9]		36 [9]				>5,000/lane (Total)
	All	No Signal								a 50 [9]	
	Fatal/Injury	No Signal			50 [9]						
Install pedestrian crossing (signed and marked with curb ramps and extensions)	All	No Signal			37 [16]						
Install pedestrian overpass/underpass	All	No Signal								r 13 [16]	
Install stop signs at alternate intersections in residential areas	All	Stop	Urban		50 [34]						
	Fatal/Injury	Stop	Urban		67 [34]						

Note: Any CRF with a reference of 43 is added to this version of the Intersection Safety Issue Brief 8.

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