The National Academies of

SCIENCES • ENGINEERING • MEDICINE

TRANSPORTATION RESEARCH BOARD

Development of Crash Modification Factors for Pedestrian Crossing Treatments

Wednesday, August 23, 2017

2:00pm to 3:30pm ET

The Transportation Research Board has met the standards and requirements of the Registered Continuing Education Providers Program. Credit earned on completion of this program will be reported to RCEP. A certificate of completion will be issued to participants that have registered and attended the entire session. As such, it does not include content that may be deemed or construed to be an approval or endorsement by RCEP.

RCEP

REGISTERED CONTINUING EDUCATION PROGRAM

Purpose

Discuss NCHRP Report 841.

Learning Objectives

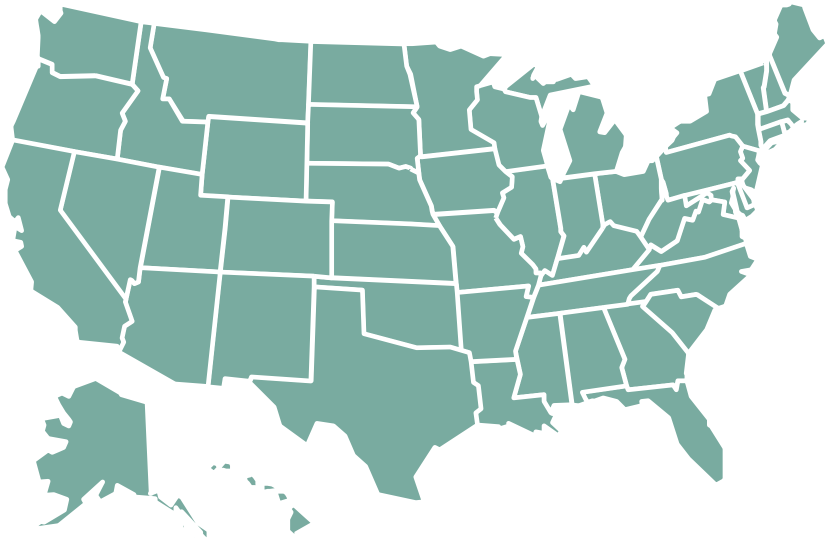
At the end of this webinar, you will be able to:

- Understand the safety effects of several common safety measures for pedestrian safety
- Describe the practices of two cities on how they select and apply such treatments
- Understand the lessons from applying safety measures for pedestrian safety

NCHRP Research Report 841: Development of Crash Modification Factors for Uncontrolled Pedestrian Crossing Treatments NCHRP Project 17-56

NCHRP is a State-Driven Program

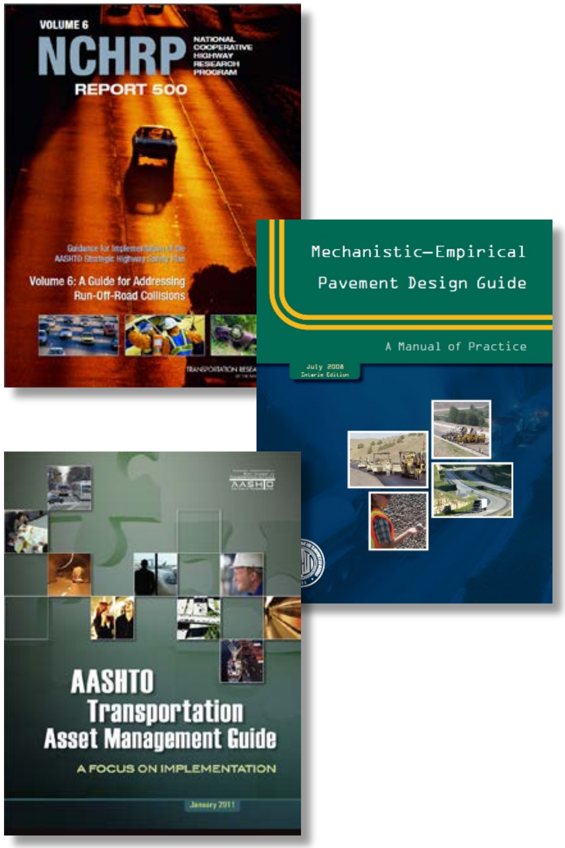
- Sponsored by individual state DOTs who
  - Suggest research of national interest
  - Serve on oversight panels that guide the research.



- Administered by TRB in cooperation with the Federal Highway Administration.

Practical, ready-to-use results

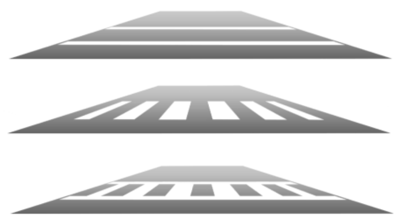
- Applied research aimed at state DOT practitioners
- Often become AASHTO standards, specifications, guides, syntheses
- Can be applied in planning, design, construction, operations, maintenance, safety, environment



Today's Speakers

- *Charlie Zegeer, University of North Carolina Highway Research Center*
- *Richard Nassi, Pima Association of Governments*
- *Michael Frederick, City of St. Petersburg*
- *Joe Fish, Toole Design Group (Moderator)*

NCHRP 17-56: Development of Crash Reduction Factors for Uncontrolled Pedestrian Crossing Treatments



August 23, 2017

Presentation Overview

- Team Overview/Project Background
- Treatment Types
- Task Approach & Data collection
- CMF development
- Results
- NCHRP 17-56 Implementation Opportunities
- Questions/Discussion

Team Overview – Project Team

Team Member	Role
Charlie Zegeer, HSRC	Project PI
Raghavan Srinivasan, HSRC	Statistical Analysis
Bo Lan, Statistician Daniel Carter, HSRC	Statistician Oversee Data Collection
Carl Sundstrom, HSRC	City & Site Selection
Sarah Smith, HSRC	Project Coordination
Kittelson and Associates, Inc (John Zegeer, Erin Ferguson)	Data Collection & Implementing Results
Persaud & Lyon, Inc	Statistical Analysis
CERS (Ron Van Houten)	Technical Advisor

Evaluation of Four Treatment Types

1. Un-signalized advance yield or stop signs and pavement markings (AS)
2. High-intensity activated crosswalk signals (PHB)
   – Also referred to as High-intensity Activated CrossWalK (HAWK)
3. Rectangular rapid flashing beacons (RRFB’s)
4. Pedestrian refuge islands (RI)

Data Collection
City Selection

- Based on detailed information obtained from each city in terms of available treatments, U.S. distribution of cities, and other factors, 14 cities were selected for the study

Alexandria, VA	Arlington, VA
Cambridge, MA	Chicago, IL
New York City, NY	Miami, FL
St. Petersburg, FL	Tucson, AZ
Scottsdale, AZ	Phoenix, AZ
Portland, OR	Eugene, OR
Charlotte, NC	Milwaukee, WI

Data Collection
Cities and Sites by Treatment Type

CITY (14 Cities)	AS	RI	RRFB	PHB	TREATMENT SITES	COMPARISON SITES
TOTAL as of 16 Jan 2015	294	319	52	97	**509**	**485**

Data Collection
Treatment Selection

- Concentrated on evaluating four treatments based on available project funds, existing data available, and importance of CMF development
  - Advance Yield or Stop Pavement Markings and Signs
  - Pedestrian Hybrid Beacons
  - Rectangular Rapid Flashing Beacons
  - Pedestrian Refuge Areas/Islands

Advanced Yield or Stop Markings and Signs

Advance yield line (shark's teeth) & sign

2009 MUTCD Section 3B.16 and Figure 3B-17

Advance stop line and sign

2009 MUTCD Section 3B.16

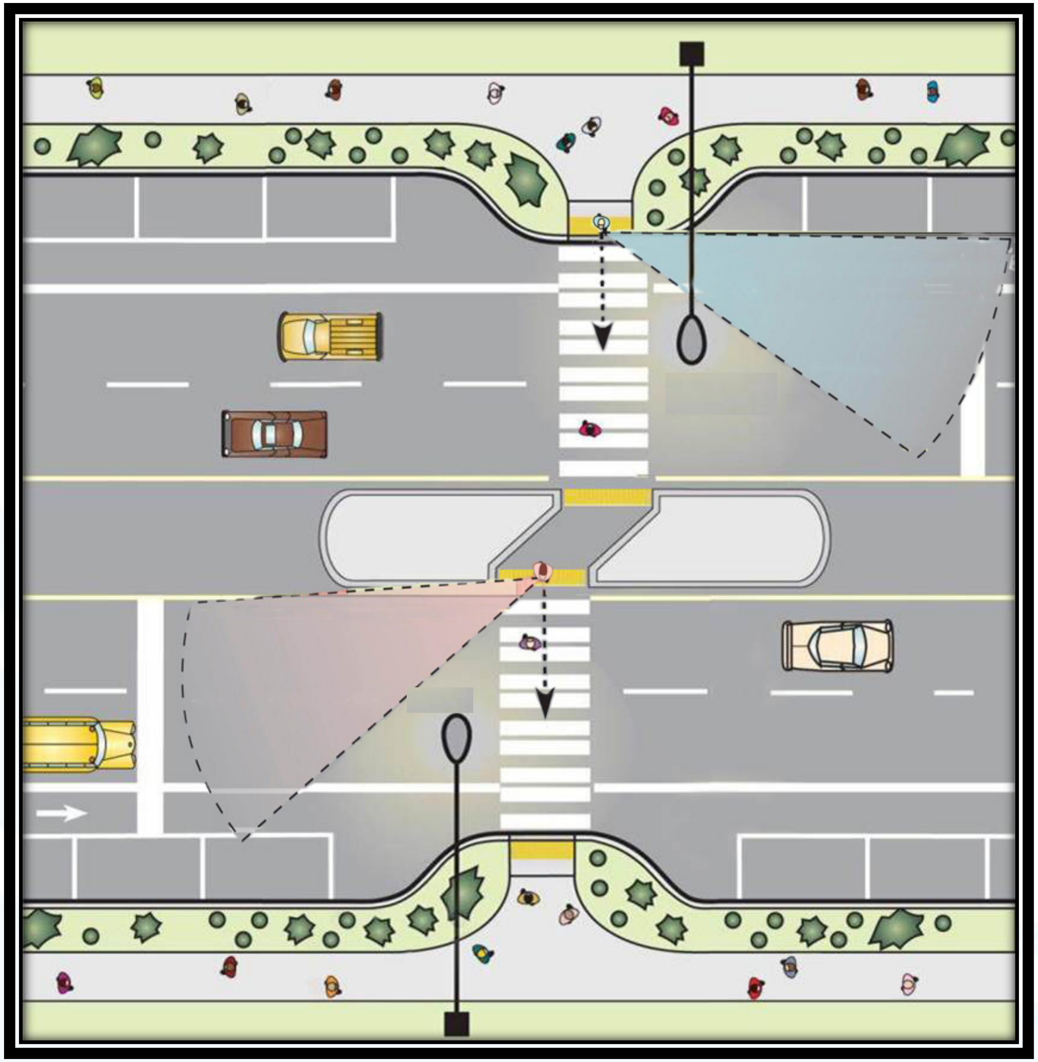
Pedestrian Hybrid Beacon

2009 MUTCD Chapter 4F Pedestrian Hybrid Beacons

Rectangular Rapid Flashing Beacons

- Beacon is yellow, rectangular, and has a rapid “wig-wag” flash
- Beacon located between the warning signs and the arrow plaque
- Must be pedestrian activated (push button or passive)
- Beacons required on both right and left sides or in a median (if practical)

Pedestrian Refuge Areas



Crossing island at marked crosswalk – breaks long complex crossing into two simpler crossings

Advanced Stop/Yield Markings and Signs (AS)

CITY	Advance Stop/Yield
St. Petersberg, FL	113
Phoenix, AZ	16
Tucson, AZ	83
Charlotte, NC	2
Miami, FL	3
Scottsdale, AZ	4
Milwaukee, WI	0
Portland, OR	53
New York, NY	0
Arlington & Alexandria, VA	4
Eugene, OR	3
Cambridge, MA	10
Chicago, IL	3
TOTAL	**294**

Pedestrian Hybrid Beacons (PHB)

CITY	PHB
St. Petersberg, FL	3
Phoenix, AZ	5
Tucson, AZ	82
Charlotte, NC	2
Miami, FL	0
Scottsdale, AZ	2
Milwaukee, WI	0
Portland, OR	2
New York, NY	0
Arlington & Alexandria, VA	1
Eugene, OR	0
Cambridge, MA	0
Chicago, IL	0
TOTAL	**97**

Rectangular Rapid Flashing Beacons (RRFB)

<u>**CITY**</u>	<u>**RRFB**</u>
St. Petersberg, FL	32
Phoenix, AZ	1
Tucson, AZ	0
Charlotte, NC	0
Miami, FL	5
Scottsdale, AZ	0
Milwaukee, WI	1
Portland, OR	2
New York, NY	0
Arlington & Alexandria, VA	2
Eugene, OR	6
Cambridge, MA	0
Chicago, IL	3
TOTAL	**52**

Refuge Area/Island (RI)

CITY	Refuge Island
St. Petersberg, FL	19
Phoenix, AZ	11
Tucson, AZ	36
Charlotte, NC	34
Miami, FL	28
Scottsdale, AZ	18
Milwaukee, WI	12
Portland, OR	40
New York, NY	17
Arlington & Alexandria, VA	26
Eugene, OR	28
Cambridge, MA	17
Chicago, IL	33
TOTAL	**319**

Total Treatment and Comparison Sites

CITY	Treatment	Comparison
St. Petersberg, FL	116	45
Phoenix, AZ	18	16
Tucson, AZ	85	65
Charlotte, NC	36	112
Miami, FL	31	38
Scottsdale, AZ	19	16
Milwaukee, WI	12	18
Portland, OR	61	33
New York, NY	17	24
Arlington & Alexandria, VA	30	28
Eugene, OR	29	27
Cambridge, MA	19	26
Chicago, IL	36	37
TOTAL	**509**	**485**

Treatment Combinations

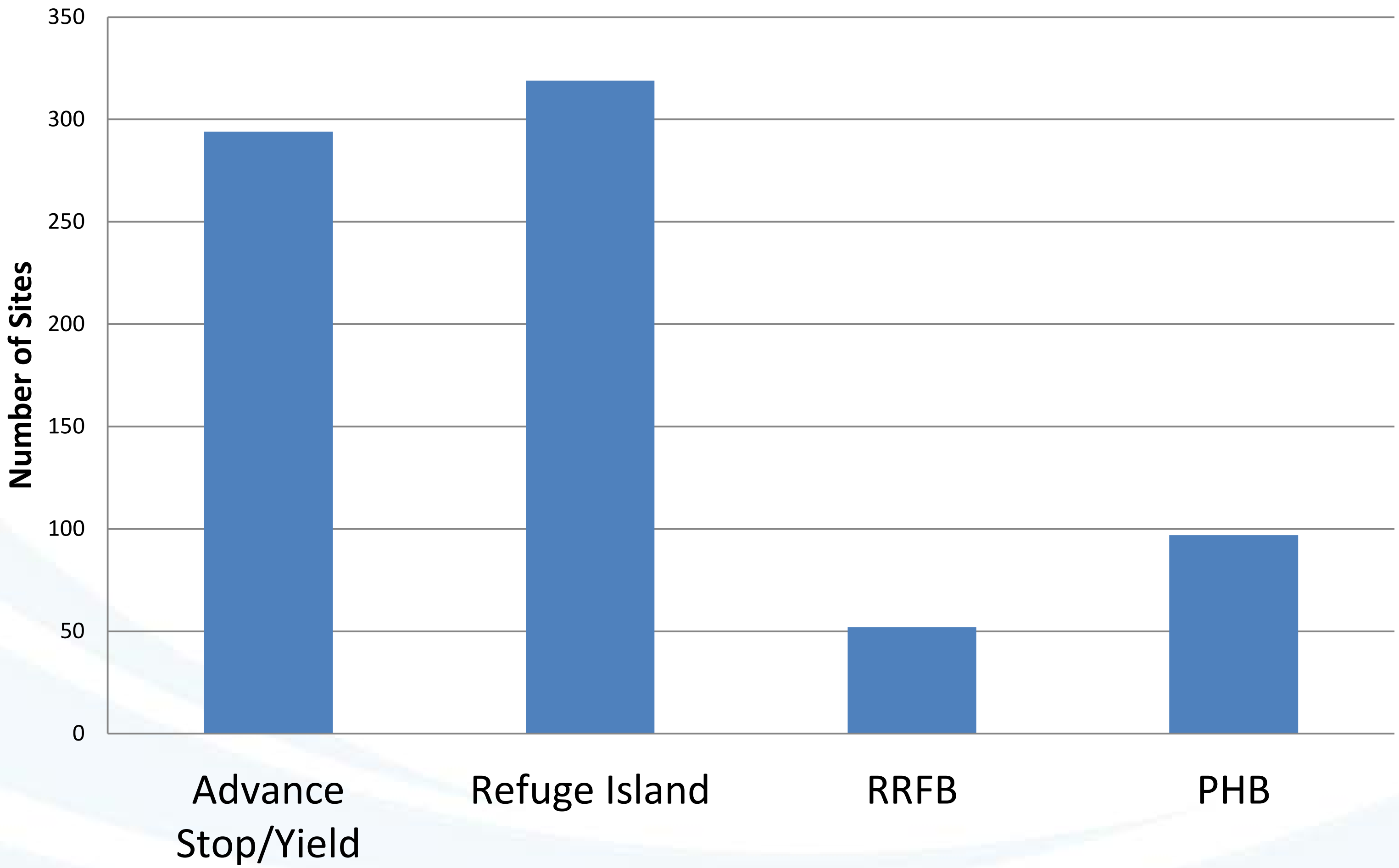
Treatment Combination Type	Number of Sites
AS	98
PHB	3
RRFB	5
RI	203
AS+PHB	57
AS+RRFB	26
AS+RI	59
RI+RRFB	4
AS+RRFB+RI	17
AS+PHB+RI	37
Total	**509**

309 Sites with one treatment

146 Sites with two treatments

54 Sites with three treatments

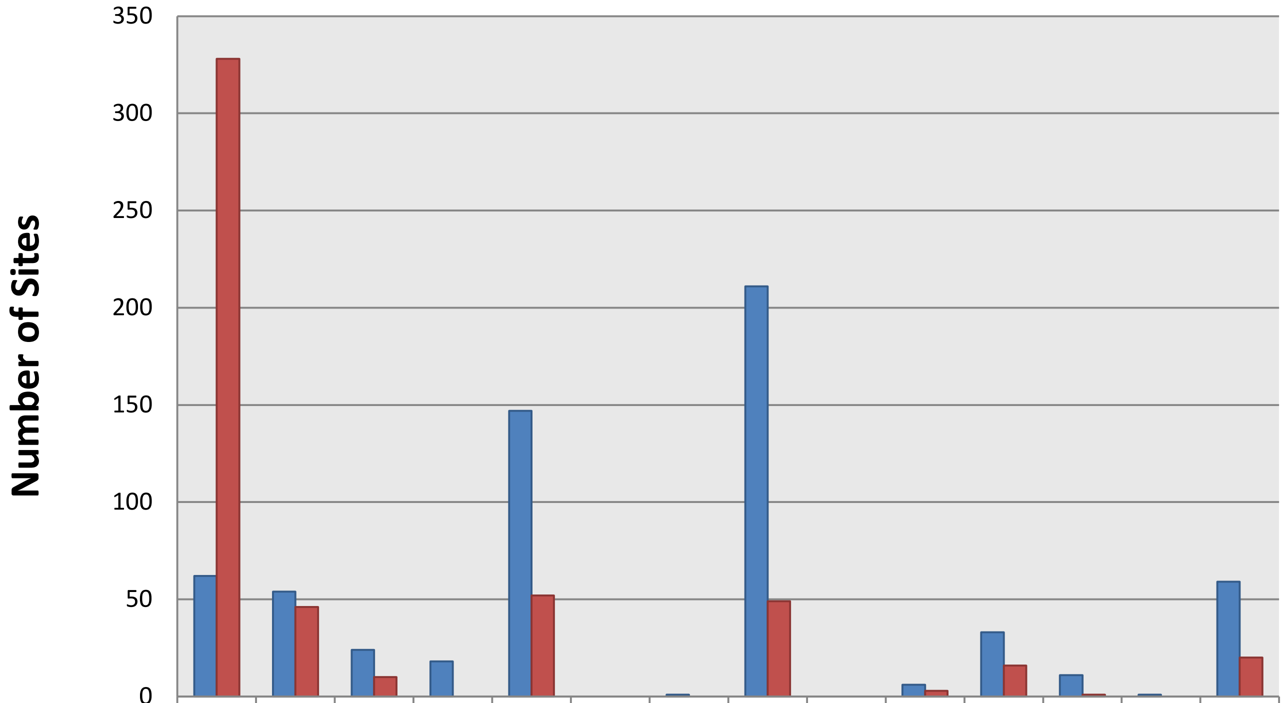
Treatment Type Totals



Data Collection
Site Characteristics

- Relevant crashes, geometric features, and volume data were collected for each site
- Other features also collected using Google Earth imagery and site photographs (signage, crosswalk type, number of lanes, intersection vs midblock, area type, transit association)
- Site characteristic histories and changes were recorded as far back as Google Earth Imagery would allow (generally 10 years)
- Data was used to develop safety performance functions (before-after studies), and disaggregate results by site type, for cross-sectional analysis

Crosswalk Type

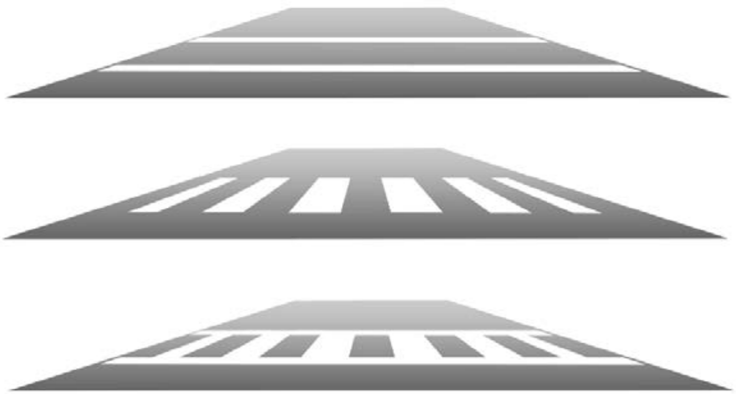


	A	B	C	D	E	F	G	H	I	J	K	L	M	Multiple
Treatment	62	54	24	18	147	0	1	211	0	6	33	11	1	59
Comparison	328	46	10	0	52	0	0	49	0	3	16	1	0	20

Type	Identifier
No Markings	A
White Std	B
Yellow	C
Staggered	D
Ladder	E
Zebra	F
Piano	G
Continental	H
Dbl. Cont	I
Diagonal	J
Brick/Stp/Blk	K
Unknown	L
Raised	M
Combined	Multiple

*Multiple refers to sites with combined crosswalk types (e.g., diagonal ladder, yellow continental, etc…)

High-visibility Crosswalk Marking Patterns



Common Crosswalk marking types

TOP-Standard

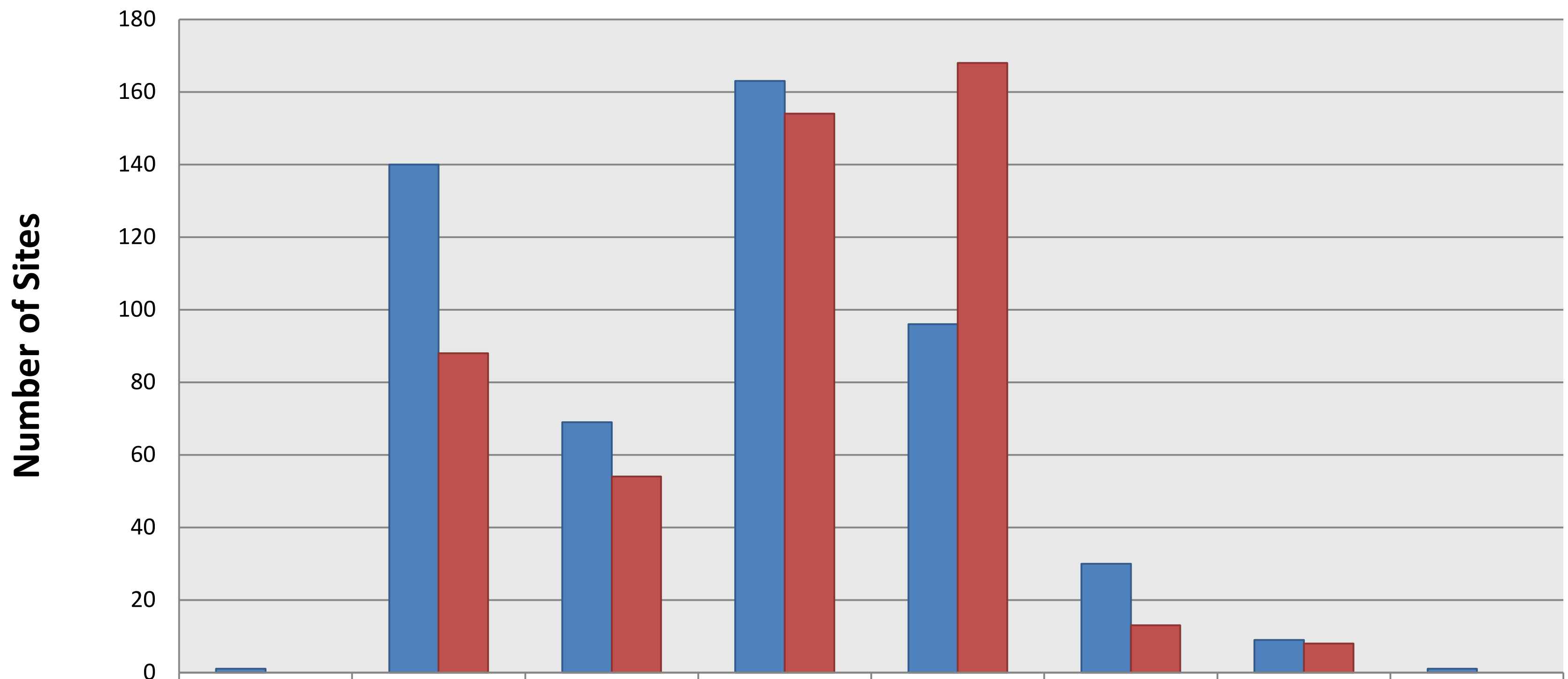
MIDDLE-Continental

BOTTOM- Ladder

Place longitudinal markings to avoid wheel tracks, reducing wear & tear & maintenance

2009 MUTCD Section 3B.18, Paragraph 15

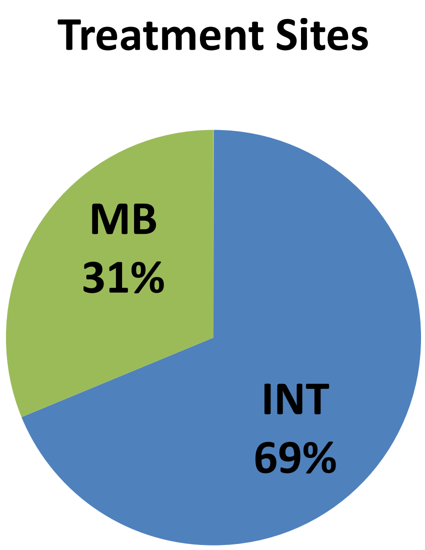
Number of Lanes

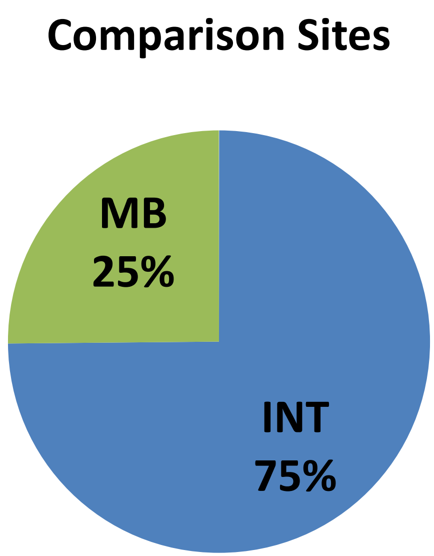


	1	2	3	4	5	6	7	8
Treatments	1	140	69	163	96	30	9	1
Comparisons	0	88	54	154	168	13	8	0

Treatments		**Comparisons**	
≤ 2 lanes	≥ 3 lanes	≤ 2 lanes	≥ 3 lanes
141 | 28%	**368 | 72%**	**88 | 18%**	**397 | 82%**

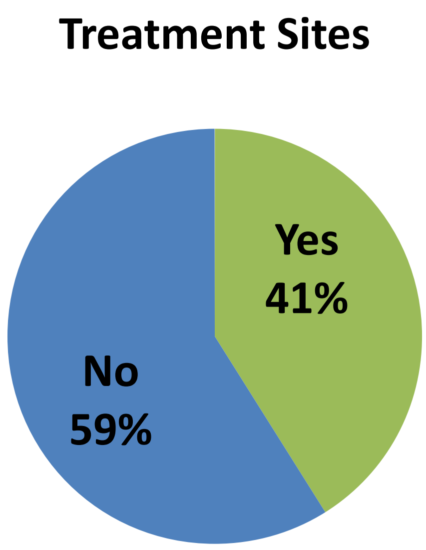
Intersection vs Mid-block

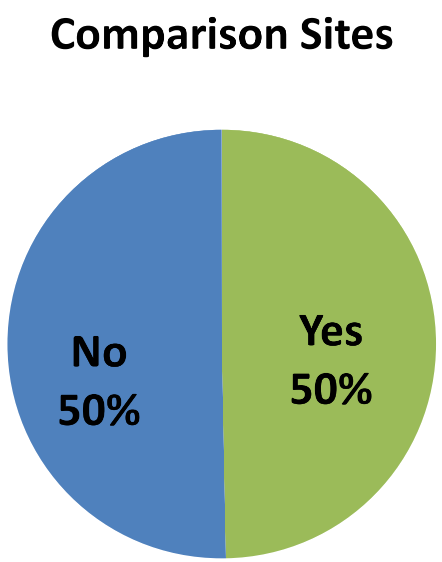




Number of Sites	Treatment	Comparison
Intersection	350	363
Midblock	159	122
Total	509	485

Transit Association





Number of Sites	Treatment	Comparison
Transit Stop (Yes)	209	241
Transit Stop (No)	300	244
Total	509	485

Data Collection of Pedestrian Volume

- Key Decisions
  - Time of day
  - Length of count
- Used Charlotte existing pedestrian volumes to determine how to proceed
- Pedestrian volumes were used to estimate pedestrian AADT's.

Data Collection
Crash and AADT Data

Crash Data Availability Summary

City	Agency to Provide Crash Data	Years of Data Available	Hard Copies Available	Data Received
Alexandria, VA	Virginia DOT	2004-2013	No	September 2014
Arlington, VA	Virginia DOT	2004-2013	No	September 2014
Cambridge, MA	Cambridge DOT	2004-2013	No	September 2014
Charlotte, NC	HSIS	2004-2013	No	November 2014
Chicago, IL	Chicago DOT	2008-2012	No	April 2014
Eugene, OR	Oregon DOT	2004-2013	No	November 2014
Miami, FL	Florida DOT	2006-2012	No	December 2014
Milwaukee, WI	Wisconsin DOT	2004-2013	No	November 2014
New York City, NY	New York DOT	2008-2012	No	October 2014
Phoenix, AZ	Arizona DOT	2004-2013	No	December 2014
Portland, OR	Oregon DOT	2004-2013	No	November 2014
St Petersburg, FL	Florida DOT	2006-2012	No	December 2014
Scottsdale, AZ	Arizona DOT	2004-2013	No	December 2014
Tucson, AZ	Arizona DOT	2004-2013	No	December 2014

CMF Development

1. Quantify the relationship between pedestrian safety and crossing treatments at uncontrolled locations
2. Develop Crash Modification Factors (CMFs) or functions (CMFunctions) by type and severity for four treatments
3. May have different CMFs for midblock vs intersection sites, or for varying ADT, number of lanes, etc.

Understanding CMFs

Crash modification factor (CMF) is a multiplicative factor used to compute the expected number of crashes after implementing a given countermeasure at a site.

$$\text{CMF} = \frac{\text{Expected crashes with countermeasure}}{\text{Expected crashes without countermeasure}}$$

CMF > 1	CMF < 1
Indicates an expected increase in crashes	Indicates an expected decrease in crashes

Understanding CMFs

Crash modification factor (CMF) is a multiplicative factor used to compute the expected number of crashes after implementing a given countermeasure at a site.

$$\text{CMF} = \frac{\text{Expected crashes with countermeasure}}{\text{Expected crashes without countermeasure}}$$

Which of the following CMFs would indicate an expected crash reduction of 25% ?

A 0.25

B 1.25

C 0.75

Understanding CMFs

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Crash modification factor (CMF) is a multiplicative factor used to compute the expected number of crashes after implementing a given countermeasure at a site.

$$\text{CMF} = \frac{\text{Expected crashes with countermeasure}}{\text{Expected crashes without countermeasure}}$$

If a treatment with a CMF of 1.25 were applied at a given site, how would the crashes at the site change?

A	Decrease by 25%
B	Increase by 25%
C	Increase by 75%

Understanding CMFs

Crash modification factor (CMF) is a multiplicative factor used to compute the expected number of crashes after implementing a given countermeasure at a site.

$$\text{CMF} = \frac{\text{Expected crashes with countermeasure}}{\text{Expected crashes without countermeasure}}$$

If a treatment with a CMF of 1.25 were applied at a given site, how would the crashes at the site change?

A	Decrease by 25%
B	Increase by 25%
C	Increase by 75%

CMF Development
Possible Approaches

- Two possible approaches for estimating CMFs:

1. Before/After Studies
2. Cross-Sectional Studies

CMF Development
Before-After Method Issues

- Two problems with relying solely on before-after analysis method
  1. Unavailability of before treatment pedestrian volumes at most of the treated sites (treatment itself may significantly change pedestrian exposure)
  2. The difficulty in obtaining sufficiently large samples of sites with a particular treatment or treatment combination within certain time frame

CMF Development
Cross-sectional Models

- Cross-sectional models may produce less reliable CMFs
- Alternative regression models with and without selected factors
- Nearby comparison sites without the treatment
- Data was combined from multiple jurisdictions for the same treatment to provide more reliable CMFs
- Goal was to conduct before-after analyses when possible (e.g., St. Petersburg, FL RRFBs)

Study Results

CMF Values

Treatment	CMF	CRF	Source (B/A or X-section study)
Refuge Islands	0.68	32%	2 studies
Advance Yield/Stop Sign	0.75	25%	2 studies
PHB ("HAWK")	0.45	55%	2 studies
RRFB	0.53	47%	X-section study

NCHRP 17-56 Implementation Opportunities

- AASHTO's Highway Safety Manual, second edition (HSM-2)
- FHWA CMF Clearinghouse
- FHWA Proven Safety Countermeasures website
- NCHRP Report 600 Human Factors Guidelines for Road Systems, Second Edition
- Manual on Uniform Traffic Control Devices (MUTCD)
- Design guidance for uncontrolled pedestrian crossings

Design Guidance for Uncontrolled Pedestrian Crossings

- State and local agencies frequently establish their own guidelines and/or procedures for when to mark an uncontrolled crosswalk and if or what supplemental treatments to install at a marked crosswalk across on an uncontrolled approach

- Supplement to the 2005 study from FHWA *Safety Effects of Marked versus Unmarked Crosswalks* by Zegeer et al. is used as a resource for developing the guidelines and/or procedures

- To facilitate these updates, FHWA is currently developing a Model Pedestrian Crossing Policy, which is incorporating the results from this study.

HAWK -- PEDESTRIAN HYBRID BEACON (PHB) QUESTIONS AND FUTURE MUTCD CONSIDERATIONS

MUTCD Changes
Design
Cost
Priority Locations
2 Stage HAWK
Roundabout HAWK
BikeHAWK
PUFFIN HAWK

ROAD USER BEHAVIORS AT HAWKS (PHB) FHWA TECHNICAL BRIEF (FHWA-HRT-16-039, JUNE 2016)

- Driver Compliance Consistently Averages 96%+
- Pedestrian Compliance Average 91%
- Only 5% of the drivers remained stopped during the Flashing RED indication when PHBs have been used for some time in the region (New MUTCD sign(s) for PHBs under consideration)
- Majority of the studied locations were at intersections
- The posted 45mph street(s) had the highest compliance rates by pedestrians
- Conflicts were mostly caused by pedestrians who did not activate the beacon
- HAWKs or (PHBs) have a significant crash modification factor at either intersection or midblock crosswalks

FUTURE MUTCD: HAWK-PHB O.K. AT INTERSECTIONS UNDER CONSIDERATION

- Section 4F.02, paragraph 04

  Guidance:

  "When an engineering study finds that installation of a pedestrian hybrid beacon is justified, then the PHB should be installed at least 100 feet from side streets or driveways controlled by STOP or YIELD signs."
- "Guidance" not a "**Standard**"
- NCUTCD voted to remove that Guidance
- Standard recommended for next MUTCD by NCUTCD:

  "If a pedestrian hybrid beacon is installed at or immediately adjacent to an intersection with a side road, vehicular traffic on the side road shall be controlled by STOP signs."

DRIVERS DO NOT WAIT AT A DARK HAWK BEACON

- FHWA 2016 HAWK study shown that drivers do not stop at non-illuminated HAWKs - PHBs when they are dark and no pedestrians are crossing. Drivers react similarly to a dark railroad signal and only stop when the lights are on.

FUTURE MUTCD: ADDITIONAL RED CLEARANCES ARE ALLOWED

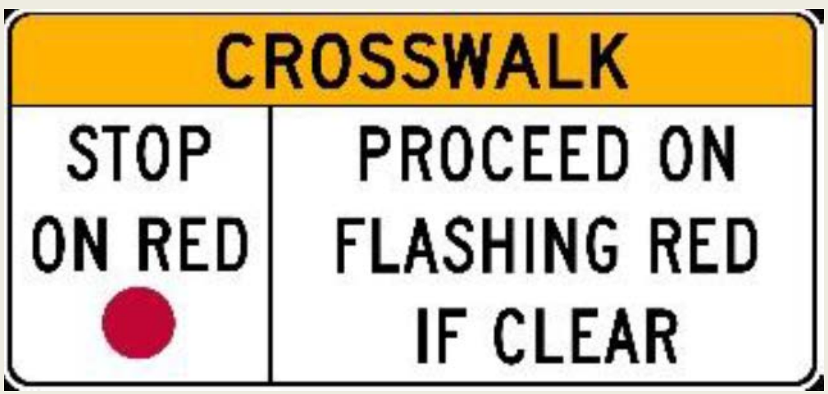
MUTCD Section 4F.02 option RED clearance and change, buffer intervals allowed at intervals 4 and 5

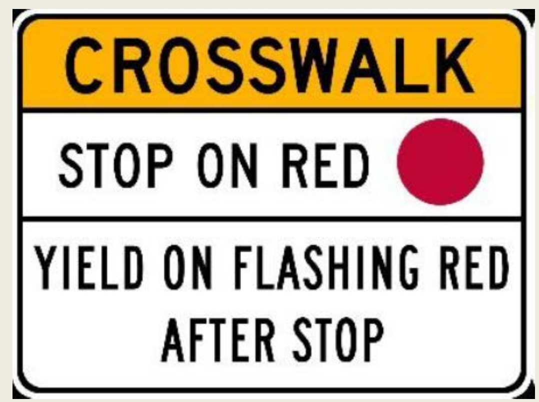
2009 MUTCD MANDATED SIGN MAY CHANGE IN THE NEXT MUTCD

- **Standard:**
  A CROSSWALK STOP ON RED (symbolic circular red) (R10-23) sign may be causing drivers to wait through all of the RED indications, if they are not familiar with the HAWK system

NEW SIGNS TO REDUCE WAITING DRIVERS DURING THE FLASHING RED

FHWA IA Available

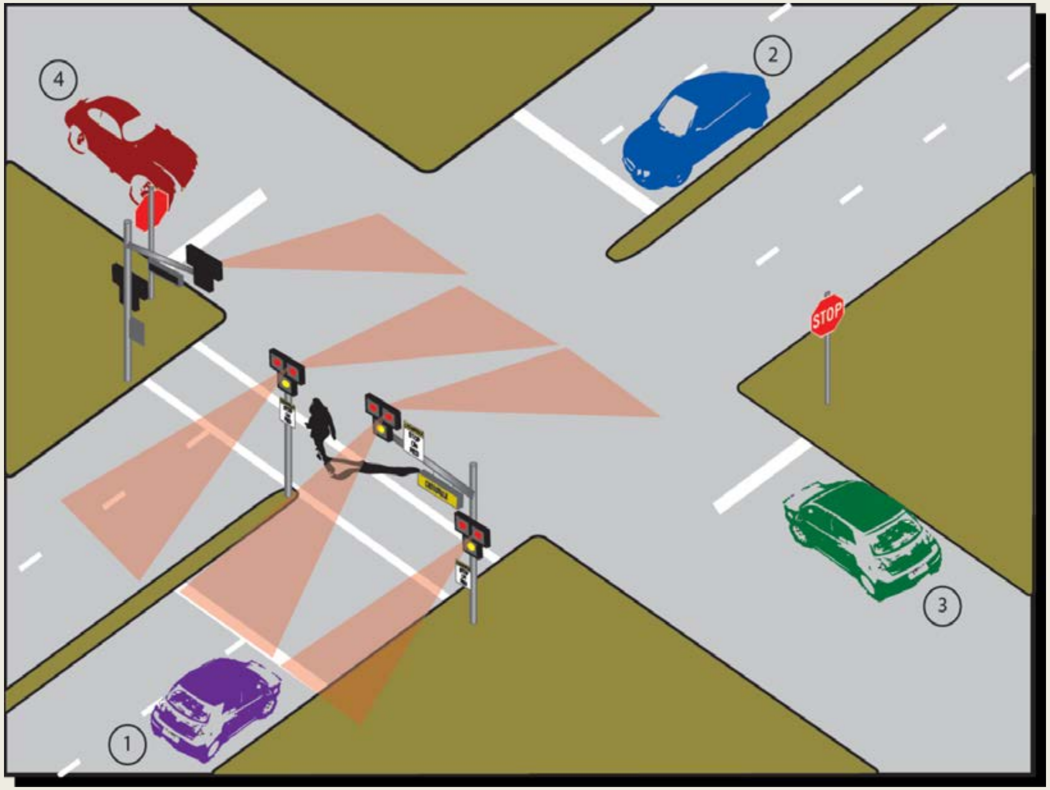




2016 FHWA Study found– No longer needed in cities, where after so many years of service, only 5% drivers now wait at a FLASHING RED

DESIGN AT INTERSECTIONS

- If used at an intersection or driveway, the HAWK beacon signal equipment only controls the crosswalk it is adjacent to:



Sources: ITE Traffic Control Devices Handbook, 2nd Edition, Pima Association of Governments and City of Tucson

HAWK SYNCHRONIZATION WITH ADJACENT SIGNALS NOT ALWAYS DESIRABLE

- Relatively quick WALK increases pedestrian compliance & encourages use of HAWK (PHB)
- If WALK service is delayed, pedestrians who have pushed the button, cross in natural gaps "early" & the motorists will be stopped after pedestrian is gone, thus diminishing respect for PHB and increasing unnecessary delays
- FLASHING RED interval keeps the delay to a minimum so synchronization may frequently not be needed
- Compliance by pedestrians is significantly increased, improving safety with minimal to no negative service level issues, when PHB is not set into synchronization with the signal system

HAWK – PHB COST

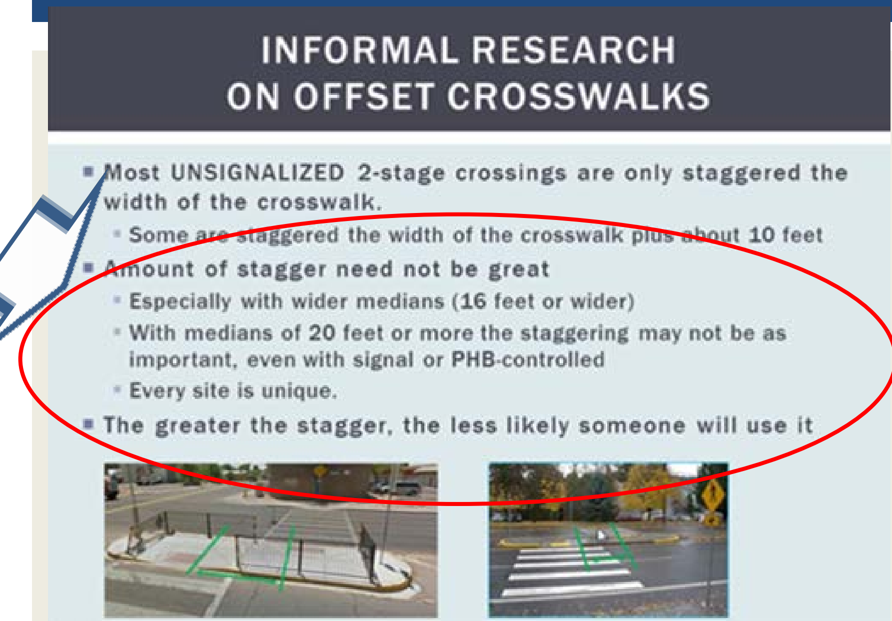
Infrastructure	Description	Median	Average	Minimum	Maximum	Cost Unit	No. of Observations
HAWK-Pedestrian Hybrid Beacon	Beacon-Signal Equip/Poles Installed	$51,460	$57,680	$21,440	$128,660	Each	9 (9)

Source: *Costs for Pedestrian and Bicyclist Infrastructure Improvements: A Resource for Researchers, Engineers, Planners, and the General Public*, October 2013

HAWK (PHB) LOCATION'S PRIORITY FACTORS

- Prioritize <u>warranted locations</u> using a point system based on:
  - Traffic volume during the peak pedestrian crossing time
  - Peak hour pedestrian volume
  - Pedestrian crashes
  - Crossing width (number of lanes)
  - Distance to nearest controlled crossing
  - Posted speed
  - Presence of a raised median
  - Crossing is a designated trail, school crossing, or SRTS walking route
  - Presence of elderly or disabled pedestrians
  - Others (lighting, curved roads, other unusual road conditions, etc.)

HAWK PHBs MAY BE SET UP AS A TWO-STAGE CROSSING



- Some PHBs may be operated as TWO-STAGE crossings which allows for great efficiency for vehicles and less delay for pedestrians
- Staggering distance, if used, of Crosswalks may vary

HAWK (PHB) AT ROUNDABOUTS

- Public Right-of-Way Accessibility Guidelines (PROWAG)
- Potentially at all multilane roundabouts

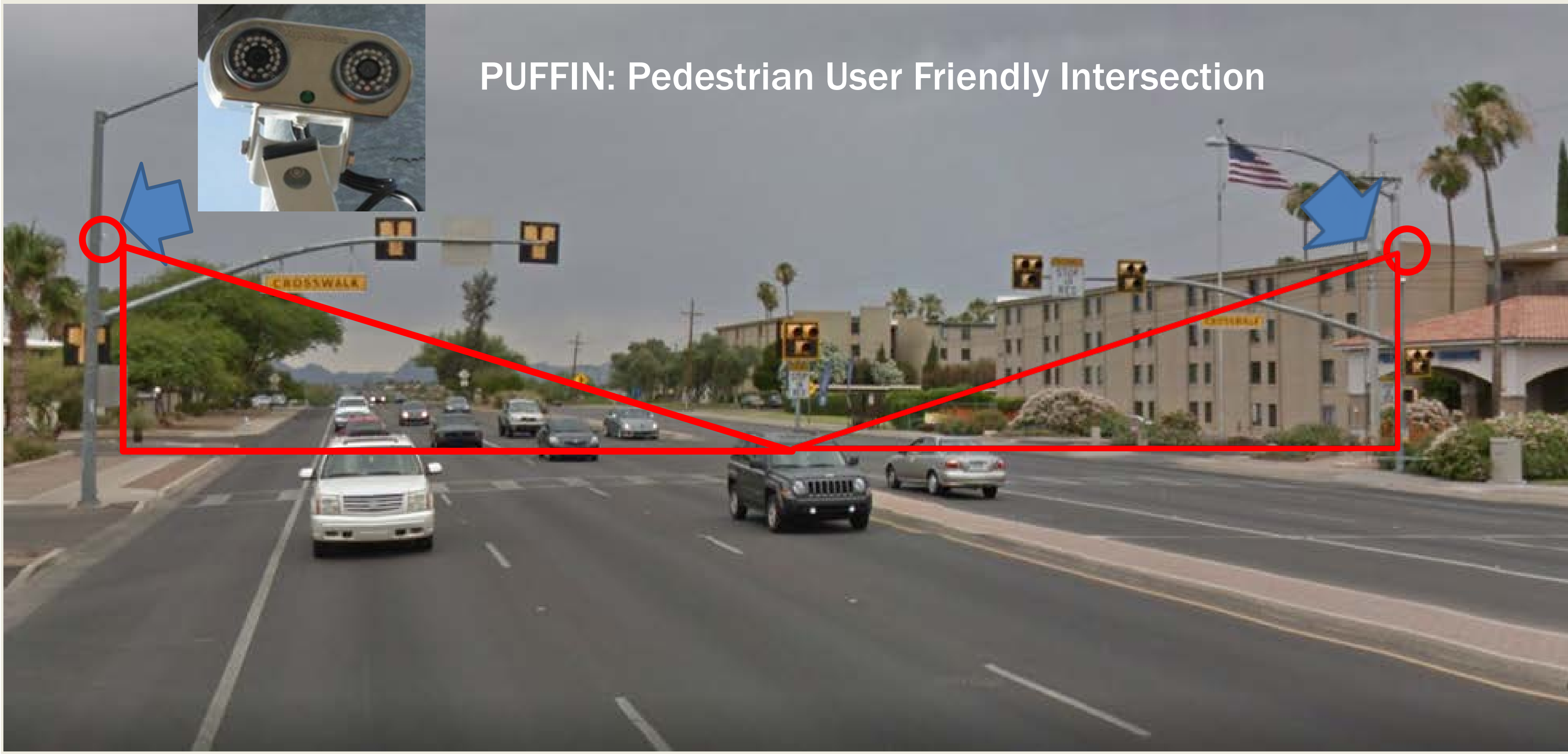
BIKEHAWK--PHB AT BIKE-PEDESTRIAN CROSSINGS (GREEN ZEBRA STRIPES)

Matches Cyclists Behavior, MUTCD Approved (IA) for GREEN

MUTCD compliant **pedbikeinfo.org** BikeHAWK: Adapting Pedestrian Hybrid Beacon to aid bicycles crossing busy streets

Bicycle Compliance is in the 90% range & near 100% with cycling families and children
Driver Compliance 96%+ range, been in operation for approximately 6+ years

PUFFIN HAWK AT PHB CROSSINGS, EXTENDS RED FOR SLOWER PEDESTRIANS



Sensors extend FLASHING ALTERNATING RED for pedestrians remaining in the crosswalk that need extra time once the FLASHING DON'T WALK has timed out.

HAWK (PHB) CROSSING QUESTIONS AND FUTURE MUTCD CONSIDERATIONS

- Thank You

Yes, that is me crossing at one of the first HAWKs installed back in the early 2000s, in Tucson Arizona

CityTrails™ St. Petersburg

First RRFB Installation - 2006

Various Installation Configurations

4-lanes: No median

Various Installation Configurations

3-lanes / One-way: Side median

Various Installation Configurations

4-lanes: Split / “Z” Crossing

Various Installation Configurations

Stand Alone Bicycle Push Button

Various Installation Configurations

5-Lane with Median – Pinellas Trail

Various Installation Configurations

Overhead

Various Installation Configurations

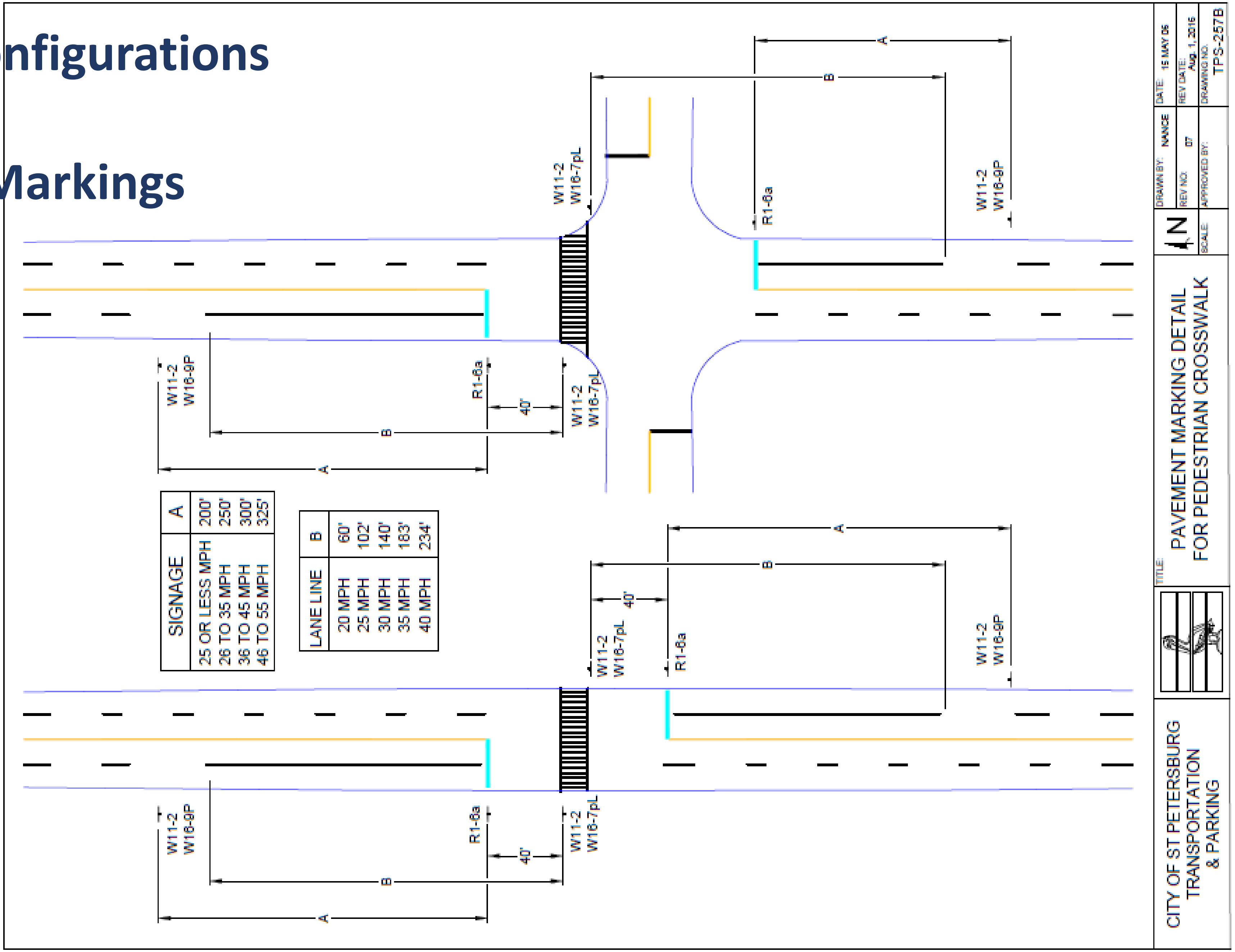
Round a bouts

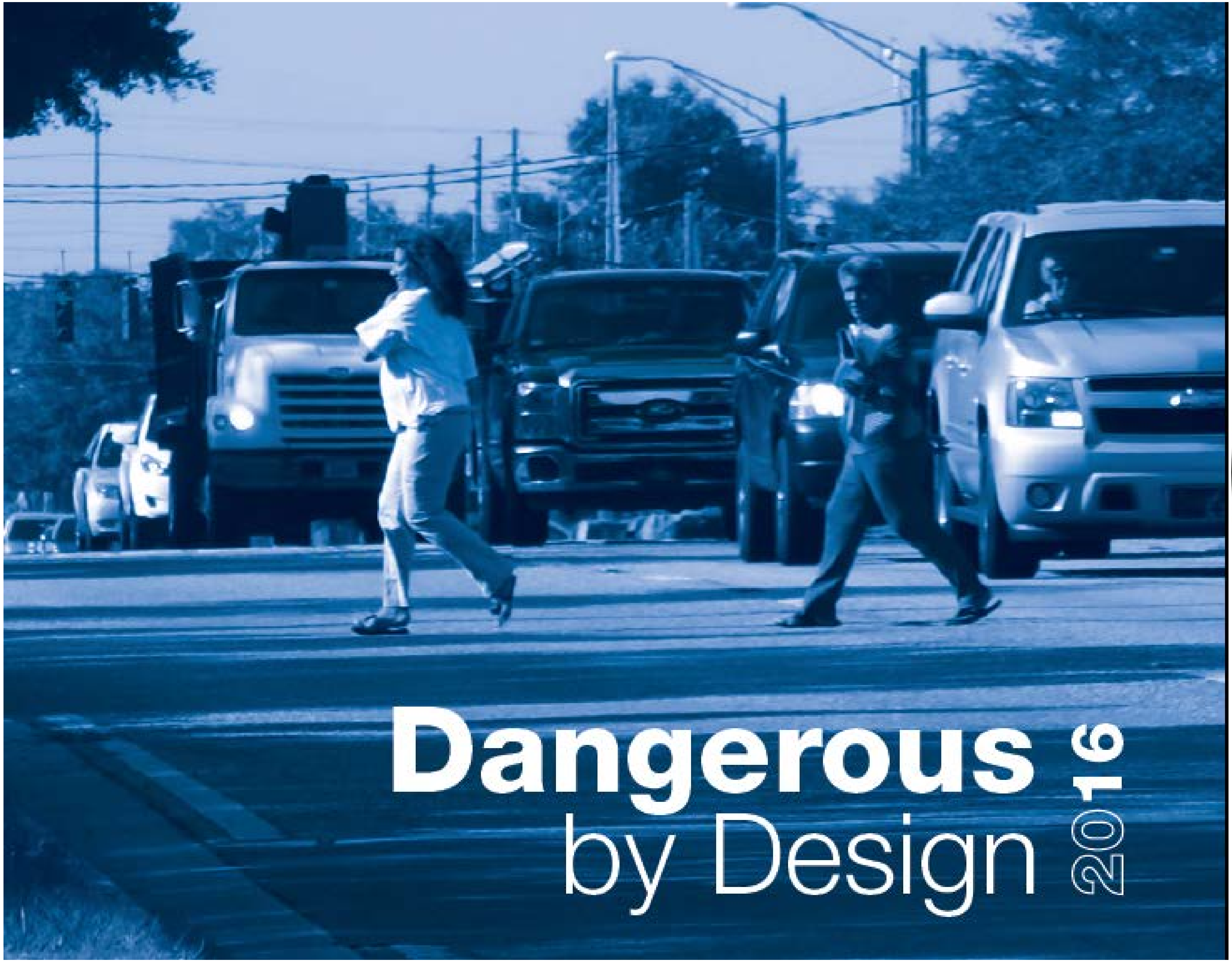
Various Installation Configurations
US 92

Pedestrian Safety Enforcement Campaign Training

Various Installation Configurations

Standard Signs & Markings





GOAL – Get off the List!

Today's Participants

- Joe Fish, *Toole Design Group*, jfish@tooledesign.com
- Charlie Zegeer, *University of North Carolina Highway Safety Research Center*, Zegeer@hsrc.unc.edu
- Richard Nassi, *Pima Association of Governments, Engineering Services*, rnassi1@gmail.com
- Michael Frederick, *City of St. Petersburg, Florida*, michael.frederick@stpete.org

Pima Association of Governments

Get Involved with TRB

- Getting involved is free!
- Join a Standing Committee (http://bit.ly/2jYRrF6)
  - AFD20, AFD80
- Become a Friend of a Committee (http://bit.ly/TRBcommittees)
  - Networking opportunities
  - May provide a path to become a Standing Committee member
- For more information: www.mytrb.org
  - Create your account
  - Update your profile

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