NJ 2020 SHSP

Intersections Emphasis Area

Completed Priority Action 1.A.2.b.

Guidance document for developing systemic factors for high-risk pedestrian signalized and unsignalized intersections and systemic countermeasures.

Driving Toward ZERO Deaths

January 3, 2022

Disclaimer

The New Jersey Department of Transportation makes no guarantees as to the accuracy, completeness, or content contained in this document. This document does not contain or imply use of required practice(s), technique(s), or standard(s). This document is subject to update.

The New Jersey Department of Transportation, its officers, employees, or agents shall not be liable for damages or losses of any kind arising out of or in connection with the use or performance of information, including but not limited to, damages or losses caused by reliance upon the accuracy or timeliness of any such information, or damages incurred from the viewing, distributing, or copying of the materials contained in is document.

The materials and information provided herein are provided "as is." No warranty of any kind, implied, expressed, or statutory, including but not limited to the warranties of non-infringement of third-party rights, title, merchantability, fitness for a particular purpose, and freedom from computer virus, is given with respect to the contents of this document or its hyperlinks to other Internet resources.

Guidance on Factors and Risk-Based Analysis for Severe Pedestrian Crash Mitigation at High-Risk Intersections

Introduction

Intersection crashes account for approximately 30% of all fatality and serious injury (FSI) crashes in the New Jersey State (Based on crash data for the years 2014-2018). About 24% of the intersection FSI are pedestrian crashes. Up to the year 2020, New Jersey was a focus State for both intersection and pedestrian safety which meant that the FSI crash rates were higher than the national average. In turn, many efforts are already in process to eliminate pedestrian intersection FSI crashes where the focus has been to mitigate high crash locations.

In addition to safety improvement projects at high crash locations, New Jersey recognizes that a systemic approach is needed to meet its strategic highway safety planning (SHSP) goals in eliminating pedestrian crashes. A systemic approach is a data-driven, networkwide (or system-level) approach to identifying and treating high risk roadway features correlated with specific or severe crash types. Systemic approaches seek to not only address locations with prior crash occurrence but also those locations with similar roadway or environmental crash risk characteristics. This type of approach enables agencies to identify, prioritize, and select appropriate countermeasures for locations with a high risk of intersection pedestrian-related crashes, regardless of crash history.

As part of the New Jersey 2020 Strategic Highway Safety Plan, the Intersections Emphasis Area Team performed a review of literature for systemic pedestrian safety analysis and identified relevant key risk factors and approach that should be considered for implementing safety improvements at the high-risk locations.

The Intersections Emphasis Area Team reviewed the National Cooperative Highway Research Program (NCHRP) Report 893 from 2018, "Systemic Pedestrian Safety Analysis." The report provides a safety analysis method that can be used to proactively identify sites for potential safety improvements based on specific risk factors for pedestrians. The report captures various risk factors for pedestrians at intersections. The Team also reviewed the FHWA Guide for Scalable Risk Assessment Methods for Pedestrians and Bicyclists ((FHWA-SA-18-032, July 2018) that outlines steps to develop risk values at various desired geographic scales. Other literature was also reviewed as part of this effort and is referenced throughout this document.

Systemic Approach

The NCHRP 893 Guidebook provides a seven (7) step process for Systemic Pedestrian Safety Analysis as shown in Figure 1. The process includes defining the scope/area of analysis, collection and compilation of available/required data, determining the primary and secondary risk factors following a data analysis, identifying which locations will benefit from deployment of a countermeasure, reviewing various countermeasures or a combination of countermeasures applicable to the location, refining the countermeasures proposed based on other priorities/diagnostic/funding needs, and finally evaluating the program and project impacts.

The pedestrian systemic processes can be weaved into a broader safety management program. Table 1 shows the relationship of the pedestrian systemic process to the Highway Safety Manual process.

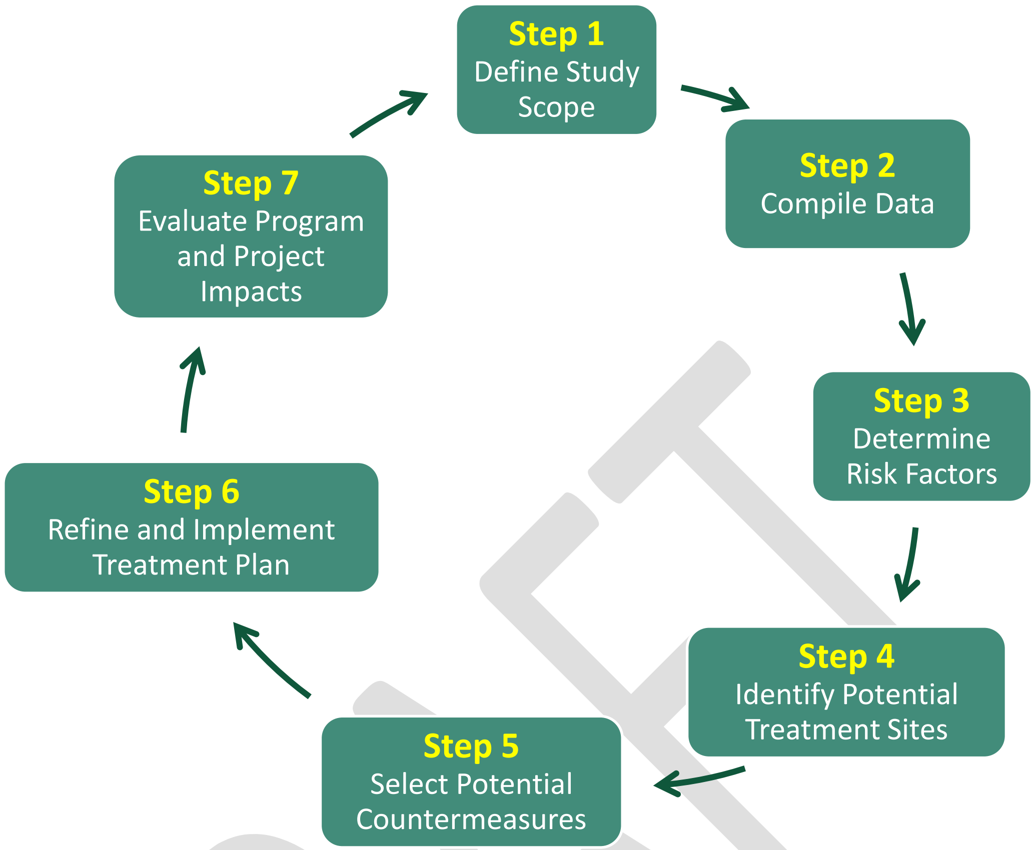

Figure 1: Steps in a systemic pedestrian safety analysis process

Source: NCHRP 893 Systemic Pedestrian Safety Analysis

Table 1: Relationship of the pedestrian systemic process to the Highway Safety Manual process

If you are in the HSM process...	Find guidance for incorporating a systemic approach in...
Prior analysis (not shown in HSM's six steps)	Steps 1–3
Network screening	Step 4
Diagnosis	Step 1 (section on identifying one or more target locations and crash types in Chapter 2), Step 3, Step 6 (section on performing additional diagnostics in Chapter 7)
Select countermeasures	Step 5
Economic appraisal	Step 6 (section on performing economic assessments in Chapter 7)
Prioritize projects	Step 6
Evaluate	Step 7

Source: NCHRP 893 Systemic Pedestrian Safety Analysis

Based on the NCHRP and FHWA guidance, a systemic approach to mitigate severe pedestrian crashes at intersections is recommended with the steps below:

1) <u>Step 1: Define Study Scope</u>

Step 1 involves defining the area for analysis, identifying the facility or location type target or focus, and identifying subsets of target crash types.

<u>For defining jurisdiction</u> – State, county and local, urban, and rural should be identified. Interstates or limited access roadways should not be included for the analysis.

<u>Identifying one or more target facility or location types</u> – Intersections, signalized and un-signalized, should be included for consideration. The location type where the crash occurred helps to determine crash context and treatment possibilities. A facility-based network screening helps in identifying high-risk facilities and also estimate risk for specified facilities within a given jurisdiction (e.g., city, county, etc.).

<u>Identifying subsets of targets crash types</u> – Pedestrian-motor vehicle crashes should be identified as the target crash type subset. The intersection crash types to be evaluated, consistent with the NJ TR-1, includes:

> *Pedestrian*- A crash involving a vehicle and pedestrian in which the collision between the two is the first event and also took place within the road. This type includes a vehicle colliding with someone walking their bicycle in the roadway.
>
> *Pedalcycle*- A crash involving a vehicle and a bicycle that is in the act of being ridden or stopped in the roadway, but currently mounted by the cyclist.

Different circumstances and maneuvers are present at different “types” of pedestrian crashes, just as for motor vehicle-only crash types. This information is useful in a systemic pedestrian safety analysis process, as it helps in diagnosing patterns systemically that are widespread and potentially treatable.

The FHWA guide provides steps to develop pedestrian and bicyclist risk values at various geographic scales. The first step in developing risk values for pedestrians and bicyclists is to define clearly the use(s) for the risk values. The use(s) of the risk values will establish key parameters (such as geographic scale) of the risk assessment process. Table 2 outlines key parameters and provides initial guidance for parameter selection based on the defined uses for the risk values. Key parameter selection will in turn help in defining the study scope for the systemic risk-based safety analysis.

Table 2: Selecting Key Parameters Based on Use(s) of Risk Values

Step 1. Define Use(s) of Risk Values	**Step 2. Select Geographic Scale**				**Step 3. Select Risk Definition**			**Step 4. Select Exposure Measure**					**Step 5. Select Analytic Method**		
	Point	Segment	Network	Regional	Observed Crash Rate	Expected Crashes	Risk Indicators	Distance Traveled	Time Traveled	Volume/Counts	Trips Made	Population	Site Count	Estimation Model	Travel Survey
Safety performance measures: Track changes in risk over time	X	X	✓	✓	✓	X	X	✓	✓	X	O	O	O	X	✓
Network screening: area-based: Identify high-risk areas for possible improvement	NA	NA	✓	✓	✓	O	O	✓	✓	X	O	O	X	O	✓
Network screening: facility-based: Identify high-risk facilities for possible improvement	✓	✓	NA	NA	✓	O	O	O	O	✓	O	O	✓	✓	X
Project prioritization: Rank projects based on existing risk or expected risk reduction	✓	✓	O	O	✓	O	✓	O	O	✓	X	X	✓	✓	X
Countermeasure evaluation: Evaluate if a specific countermeasure reduces risk (and by how much)	✓	✓	NA	NA	✓	O	O	O	O	✓	X	X	✓	O	X
Site evaluation: Evaluate if risk was reduced after site improvements (and by how much)	✓	✓	NA	NA	✓	✓	O	O	O	✓	X	X	✓	O	X

Legend: ✓= Yes, preferred; O = yes, as a secondary preference; X = Not likely; NA = Not applicable

Source: Guide for Scalable Risk Assessment Methods for Pedestrians and Bicyclists

Additional relevant resources for reference when defining the scope for analysis are as follows:

- FHWA's Guidebook for Developing Pedestrian and Bicycle Performance Measures
- FHWA's Systemic Safety Project Selection Tool

2) Step 2: Compile Data

Step 2 serves as an important foundational database to support all future steps in the process. Appendix A is a dataset identifying the various data elements that are possible systemic risk factors with relevant data sources that should be collected as part of this step.

Step 2 involves the following tasks:

i. Compile roadway data, including traffic and pedestrian volumes, for the relevant target facility types.
ii. Add land use and sociodemographic data using spatial methods to the specific locations for the relevant facility type.
iii. Count the focus crashes and add these data to the specific locations. Crash frequencies by location are the dependent (outcome) measures of safety.

Completion of the above tasks will result in a database that will provide key information for the safety analysis.

Additional relevant resources on data collection and volume estimation are as follows:

- FHWA's Synthesis of Methods for Estimating Pedestrian and Bicyclist Exposure to Risk at Areawide Levels and on Specific Transportation Facilities
- FHWA's Guide for Scalable Risk Assessment Methods for Pedestrians and Bicyclists
- FHWA's Traffic Monitoring Guide
- NCHRP Report 797: Guidebook on Pedestrian and Bicycle Volume Data Collection (Ryes et al. 2014)

3) Step 3: Determine Risk Factors

Step 3 involves analyzing data to determine factors associated with the target pedestrian crash type or location of interest or using alternate approaches from research or local knowledge to identify key risk factors.

The NCHRP Report 893 *Systemic Pedestrian Safety Analysis* provides the following as generally perceived risks for pedestrian crashes:

1. High volumes of vehicles, but infrequent interaction with pedestrians, which may lead to lower driver expectancy
2. High volume of pedestrians
3. Length of time and distance of pedestrian exposure to oncoming traffic
4. Conflict points in roadway design and operations
5. Lack of separation between pedestrians and motor vehicle paths
6. Higher speed traffic on roads with significant pedestrian activity
7. Dark or sparsely lit roads or inconspicuous crossing locations
8. Long distances or wait times between roadway crossing opportunities

A more detailed list of the possible systemic risk factors and their relevant data sources is provided in Appendix A.

The NCHRP Report 893 *Systemic Pedestrian Safety Analysis* provides a comparison of the three different basic approaches to determining pedestrian crash risk factors, which can then be used to identify sites for potential safety improvement needs. The first approach is to develop safety performance functions, or SPFs, by modeling crash counts using networkwide data and a meaningful set of traffic, roadway, land use, and other characteristics to determine risks. The other two methods are determining risk factors from a combination of prior research and local knowledge and using systemwide crash data to identify locations in the network where target crash types have occurred and the prevalent characteristics of those locations. Table 3 provides a summary of the comparison for the three different approaches to determining risk factors.

Table 3: Comparison of methods for determining risks to use in a systemic pedestrian safety process

Strengths	Limitations
Count Models (SPFs) • Uses network data. • Provides estimates that can be used to determine high potential crash locations (as well as higher risk locations) specific to the jurisdiction. • Identifies risks while controlling for other important factors such as traffic and pedestrian volume. • Data determine risks based on crash prediction. • Provides “weights” of variable importance within model. • Provides ability to estimate crashes for prioritization, economic analysis, and treatment evaluation.	• Requires effort during Step 2 to compile or estimate pedestrian volume data from different sources (roadway, crash, and other). Otherwise, data needs are similar to other methods. • Requires more modeling expertise than other methods. • May provide misleading identification of risk factors or a biased list of sites if important variables are missing from the data and modeling.
Research/Local Judgment • Does not require local crash data matched to locations. • Uses local roadway characteristics for screening. • May be simple to perform initially. • Does not require initial use of pedestrian volume data. • Smaller jurisdictions could assess risks through road safety audits.	• Assumes risk factors are similar to those from other studies or jurisdictions. • Requires local knowledge and expertise to determine risk factors. • Still requires compiling relevant data types to screen the network for risks. • May require more effort at later steps to compile additional data (to account for pedestrian demand/exposure) to prioritize zero-frequency crash locations (Step 6), if these measures are not included in the initial risk screening. • May require judgment to apply weighting factors for prioritization. • Does not produce crash estimates for project evaluation or economic analysis. • Does not produce SPFs that can be used to evaluate treatments.
Frequency-Based Method • Uses network data. • May seem more intuitive to apply. • May make a priori determinations of crash types and roadway factors that are treatable for use in identifying systemic issues.	• Expert judgment needed to make determinations of conditions relevant for countermeasures application (e.g., traffic volume and speed). • Is not built on analysis of risk factors that may contribute to crashes across the network while controlling for other factors such as traffic volume.

Strengths	Limitations
	• May not account for regression-to-the mean/random effects. • Disaggregation may obscure risks for pedestrians, especially if based on vehicle concerns. • May identify sites having features correlated with high traffic and high pedestrian volumes but potentially miss other locations with elevated risk. • May require more effort at later steps to compile additional data (to account for pedestrian demand/exposure) to prioritize zero-frequency crash locations (Step 6), if these measures are not included in the initial risk screening. • Does not produce crash estimates to evaluate projects (economic analysis) or treatments.

Source: NCHRP 893 Systemic Pedestrian Safety Analysis

In the case that using a set of predetermined risk factors is the best option, Table 4 provides a summary of factors based on previous research that have been found to have consistent relationships in the expected direction to crashes. These factors might be considered by agencies, among other locally determined factors, for risk-based screening.

Agencies should analyze ensure they are considering relevant characteristics and risk factors for their network and focus crash types.

Table 4: Potential roadway risk factors identified from prior research and relationship to pedestrian crashes at intersections

Variable/Risk Factors	Intersections
Traffic volume	Positive (generally positive but not linear)
High-turning volumes	Unknown threshold
Functional classes—arterials and collectors compared with local streets	Positive
Proportion of truck/bus traffic in traffic stream	Positive (crash severity)
Proportion of local streets at intersection (potential surrogate for AADT)	Negative
Pedestrian volume	Positive (but not linear)
Number of legs > 3 (may also be partial traffic surrogate)	Positive
Total lanes on largest leg (5+) Positive Unknown at present	Positive
No median/median island	Positive (less certain than for segments)
Presence/number of transit stops	Positive
Presence of on-street parking	Positive
Presence/number of driveways	Positive
Presence of signal	Positive with crash frequencies

Variable/Risk Factors	Intersections
	Negative with crash severity
Lack of separate turning movements from walk phase (all red walk phase, or walk and restricted turn phase) (signalized intersections)	Positive
Lack of leading pedestrian interval (signalized intersections)	Positive
Presence of four or more through lanes Higher numbers of total lanes	Theoretically yes
Speed limit > 25 mph	Unknown at present
Vehicle speed	Positive with severity

Note: Positive and negative denote correlations with crashes.
Source: NCHRP 893 Systemic Pedestrian Safety Analysis

Table 5 summarizes conditions associated with increasing pedestrian injury severity based on previous research.

Table 5: Roadway, crash, and person factors associated with increasing injury severity in pedestrian crashes

Variable	Category (if relevant)	Relationship	Evidence	Potential Data Source
Light conditions	Dark, with and without street lighting or unspecified	Positive	Strong	Crash data
Speed limit	Higher speed limits (> 25 mph)	Positive	Strong	Roadway data
Traffic control type	Other than signal (stop sign) or no control	Positive	Moderate	Roadway data
Vehicle type	Varied—larger compact to smaller, especially trucks or buses	Positive	Strong	Crash data; traffic data (% heavy vehicles)
Pedestrian age	~65 years and higher	Positive	Strong	Crash data or census data (area population %)
Pedestrian impairment	Pedestrian under influence; alcohol use suspected or detected	Positive	Strong	Crash data; locations of alcohol vendors—may be available in GIS as a potential population level surrogate
Pedestrian action	Pedestrian crossing roadway (with/without signal or at midblock)	Positive	Moderate	Crash or crash type data

Note: Strong = six or more studies with consistent direction of effect; moderate = five to six studies with consistent direction of effect.
Source: NCHRP 893 Systemic Pedestrian Safety Analysis

Additional resources for determining risk factors are as follows:

- Crash Modification Factor Clearinghouse website
- FHWA's Safety Performance Function Decision Guide: SPF Calibration verses SPF Development

- FHWA's Safety Performance Function Development Guide: Developing Jurisdiction-Specific SPFs
- NCHRP's User's Guide to Develop Highway Safety Manual Safety Performance Function Calibration Factors
- FHWA's Systemic Safety Project Selection Tool
- FHWA's Reliability of Safety Management Methods: Systemic Safety Programs
- FHWA's Evaluation of Four Network Screening and Performance Measures

Step 4: Identify Potential Treatment Sites

Step 4 involves identifying an optimal set of sites that have common risk and site characteristics that are suitable for similar packages of treatments, using various screening and ranking methods.

It is recommended to eliminate from consideration any sites that have a low expected and predicted crashes where feasible countermeasures do not exist, or where there are pending or planned projects. Sites should be identified based on estimated crash rankings.

Step 5: Select Potential Countermeasures

Step 5 involves identifying appropriate countermeasures or combinations of measures that could potentially address the risks identified.

It is recommended to establish a framework for selecting countermeasures. The NCHRP Guide provides general criteria for the countermeasure selection process as follows:

1. Relation of the countermeasures to systemic program focus or target crash types or locations
2. Safety Effectiveness based on crash evidence or research for the countermeasures
3. Cost of countermeasure application
4. Feasibility of implementing countermeasures

An initial list of potential systemic countermeasures should be developed for this Step. Table 6 provides a list of pedestrian countermeasures that were identified through research and provided in the NCHRP guidebook to serve as a starting point for agencies as they apply their own criteria to identify countermeasures suitable for systemic implementation in their jurisdictions.

Table 6: List of pedestrian crash countermeasures for potential systemic application

Suitable for Signalized Intersections Only (or where signal is added)	Suitable for Un-signalized (Locations Only midblock or intersection)	Suitable for Either Signalized or Unsignalized Crossing Locations (including midblock)
• Leading pedestrian interval • Longer pedestrian phase • Restricted left turn (protected crossing phase)	• In-roadway yield-to-pedestrian (R1-6) sign/ gateway • Advance stop/yield bar and R1-5/5a sign • PHB	• High visibility crosswalk • Traffic calming (raised device) • Median crossing island • Reduce number of lanes road diet • Curb extension and parking restriction

		• Location-specific lighting improvement

Source: NCHRP 893 Systemic Pedestrian Safety Analysis

Treatments such as general warning signs are not included in the suggested systemic countermeasures list. Countermeasures should be selected for the facility type (Intersections, segments, etc.) and risk countermeasures should target the risks identified. Treatments should be appropriate for the site conditions or context. It is recommended to utilize the NJDOT Context Sensitive Design guidance when selecting countermeasures.

To help with the process of countermeasure selection, Table 7 provides an evidence-based summary of the relationship of the countermeasure to risk factors, crash types, and the relevant location types for the 12 countermeasures presented in the NCHRP guidebook.

Table 7: Countermeasures in relation to risk factors, crash types, and location types

Countermeasure	Related Risk Factor	Related Crash Type	Location Type
High visibility crosswalk	Conspicuity (driver failure to notice); compliance with crosswalks (motorist and pedestrian)	Any occurring at crossing locations	Signalized or Unsignalized*
Traffic calming (raised crosswalk/ speed table)[1]	Traffic speed; conspicuity/pedestrian visibility (possibly); non-compliance with crosswalks	Through vehicle, pedestrian crossing at signalized/unsignalized location; turning vehicle, pedestrian crossing; pedestrian dart-outs and dashes; unique midblock crossing/pedestrian in roadway types; speeding related	Signalized or Unsignalized*
Median crossing island	Number of traffic lanes; number of lanes crossed in one maneuver; traffic speed (possibly, if roadway narrowed), turning speed at intersections (possibly, if restricts turning radius/corner cutting)	Through vehicle, pedestrian crossing at signalized/unsignalized location; turning vehicle, pedestrian crossing roadway; pedestrian dart-outs and dashes; possibly nighttime crashes if replaces two-way, center-turn lane	Signalized or Unsignalized*
Road diet	Number of lanes; number of conflict points associated with driveways/ junctions; traffic speed	Through vehicle, pedestrian crossing at unsignalized location; pedestrian dart-outs and dashes; potentially pedestrian walking along the roadway or other pedestrian in roadway types if sidewalks provided; speeding-related/potentially all types; motorist types, including rear-end and sideswipe/angle	Unsignalized*
Curb extension with parking Restriction	Parking presence; conspicuity/visibility; width of crossing	Through vehicle, pedestrian crossing at unsignalized location; pedestrian dart-outs and dashes; multiple threats; turning vehicle at intersection; waiting to cross	Unsignalized*

Countermeasure	Related Risk Factor	Related Crash Type	Location Type
Improve lighting	Conspicuity (driver failure to notice); darkness	Nighttime pedestrian crashes	Signalized or Unsignalized*
In-roadway yield to pedestrian sign (R1-6)	Conspicuity; traffic speed; traffic volume/gap availability	Pedestrian crossing, through vehicle at unsignalized location; multiple threats; motorist failure to yield	Unsignalized*
Advance stop/yield marking and R1-5/R1-5a sign	Number of traffic lanes (> 1 by direction); conspicuity/sight lines	Pedestrian crossing, through vehicle at unsignalized location; multiple threats; motorist failure to yield	Unsignalized*
PHB	Traffic volume; no traffic signal/stop sign; multiple traffic lanes (possibly)	Through vehicle at unsignalized location; motorist failure to yield; multiple threats; bus related	Unsignalized*
LPI	Conflicts at signalized locations; motorist failure to yield when turning	Pedestrian crossing, vehicle turning left or right	Signalized
Longer pedestrian phase	Conflicts at signalized locations; insufficient crossing time	Pedestrian crossing, through vehicle; pedestrian crossing, vehicle turning left or right; pedestrian failure to yield types and pedestrian dashes	Signalized
Protected crossing phase	Conflicts with turning traffic; pedestrian delay (due to turning traffic)	Pedestrian crossing, vehicle turning left; motorist failure to yield when turning	Signalized

**Unsignalized locations include midblock crossings lacking signal controls.*

[1]This countermeasure should be considered only for a residential local street or any street where the primary function is to provide access to abutting residential property, a street that provides access to a school, park, or community center, and/or for neighborhood or residential collectors.

Source: NCHRP 893 Systemic Pedestrian Safety Analysis

Table 8 provides information based on research and expert guidance on suitable contexts for the 12 countermeasures presented in the NCHRP guidebook.

Table 8: General traffic considerations and context for countermeasures

Countermeasure	Speed (Limits or General Operating Speed	Volume	Number of Lanes
High visibility crosswalk	Any; consider need for additional treatments at higher speeds	Any; consider need for additional treatments at higher volumes.	Any; consider need for additional treatments on multi-lane roads.
Traffic calming (raised crosswalk/ speed table)	Low Generally ≤30 mph	Low to moderate (< ~10,000 to 25,000 ADT)	Any
Median crossing island	Any	Any	Two or more through lanes; minimum space needed is 4 feet but ideally 8 feet
Road diet	Any	Up to 20,000–25,000 ADT (consider potential trade-offs at volumes around 20,000 AADT and up)	Three to four lanes; 5+ lanes before treatment (most research based on conversion of undivided four lane to two regular traffic lanes plus TWLTL and bike lanes or parking)
Curb extension with parking Restriction	Potentially any speed on road where parking is present.	Any	Any; consider bicycle facility type; consider large vehicles/transit effective turn radius.
Improve lighting	Any	Any	Any
In-roadway yield to pedestrian sign (R1-6)	Lower speed (≤30 mph) (Van Houten and Hochmuth 2017). But yield treatments may be insufficient at higher speed sites.	Low-to-moderate pedestrian volume Low-to-moderate ADT (<12,000) (Van Houten and Hochmuth 2017)	Two-to-four lanes (most recommended for two-lane roads); median islands provide protection for signs (Van Houten and Hochmuth 2017).
Advance stop/yield marking and R1-5/R1-5a sign	Any locations reliant on yield with multiple lanes could be considered, but yield treatments not	Low-to-high ADT (consider need for additional treatments on higher volumes)	Two or more lanes per approach direction, especially at uncontrolled crossings

Countermeasure	Speed (Limits or General Operating Speed	Volume	Number of Lanes
	recommended for higher speed roads.		
PHB	Moderate to moderately high speeds.	Low-to-medium high ADT (<10,000 to 25,000) depending on other treatments	Two or more lanes per direction
LPI	Low to moderate (≤45 mph)	Moderate to high (10,000 to >25,000)	One or more lanes
Longer pedestrian phase	Any	Higher pedestrian volumes; low-to-high motor vehicle volumes (<10,000 to >25,000)	Multiple lanes at intersection, including turn lanes
Protected crossing phase	Any	Higher pedestrian volumes; high volumes of left-turning traffic	Multiple lanes with dedicated turn lanes

Source: NCHRP 893 Systemic Pedestrian Safety Analysis

Table 9 provides information on the pedestrian safety effects (described in terms of crash modification factors (CMFs)) as well as any other safety benefits that could be documented of the 12 countermeasures presented in the NCHRP guidebook.

Table 9: Summary of CMFs and other safety benefits of systemic countermeasures

Countermeasure	CMFs and Other Estimated Pedestrian Safety Benefits	Motor Vehicle CMFs and Crash Types Effects
High visibility crosswalk	0.52 urban locations (Chen et al. 2013); 0.63 for high visibility yellow/green markings in urban school zones (Feldman et al. 2010), both replacing standard parallel markings	0.81 for angle, head on, left turn, rear end, rear to rear, right turn, and sideswipe (CMF Clearinghouse citing Chen et al. 2012)
Traffic calming (raised crosswalk/ speed table)	0.55 (CMF Clearinghouse citing Elvik and Vaa 2004 for areawide traffic calming)	0.70 serious, minor, and possible injuries (CMF Clearinghouse citing Elvik and Vaa 2004)
Median crossing island	0.68 (Zegeer et al. 2017a, b) Install raised median, 0.54 to 0.69 range (multiple CMFs available; CMF Clearinghouse citing Alluri et al. 2012a, b; Zegeer et al. 2002	0.71 – 0.74 (Zegeer et al. 2017a)
Road diet	Reducing trend in New York City study of 460 sites; no pedestrian crash CMFs yet available. Injury crash reductions expected due to lower travel speeds, fewer lanes,	0.71 average urban/suburban roads 0.53 (suburban area) 0.81 (urban area)—all types, all severities (Harkey et al. 2008)

Countermeasure	CMFs and Other Estimated Pedestrian Safety Benefits	Motor Vehicle CMFs and Crash Types Effects
	and other potential enhancements (Thomas et al. 2016).	
Curb extension with parking Restriction	0.7 for parking removal to off-street (Toolbox citing Gan et al. 2005); no CMFs yet available for curb extension. Curb extensions reduce pedestrian exposure to crossing distance and improve visibility between pedestrians and motorists. May reduce turning speeds.	Unknown/no CMFs yet available for limited parking restrictions or curb extensions.
Improve lighting	0.58 nighttime, pedestrian (CMF Clearinghouse, CMF ID 436, citing Elvik and Vaa 2004, for adding lighting, non-specified location types)	0.77 total injury crashes (Harkey et al. 2008; many CMFs available for various crash types on CMF Clearinghouse.)
In-roadway yield to pedestrian sign (R1-6)	No CMFs yet available. Motorist yielding has been highest with gateway configuration. Speed reductions in some applications (Van Houten 2017, Van Houten and Hochmuth 2017).	Unknown/no CMFs yet available
Advance stop/yield marking and R1-5/R1-5a sign	0.75 pedestrian crossing crashes 0.64 to 0.86 range (Zegeer et al. 2017a, b)	0.89 total crashes 0.80 rear-end and sideswipe crashes (Zegeer et al. 2017a, b)
PHB	0.31 (Fitzpatrick and Park 2010a, b) 0.45 (Zegeer et al. 2017a, b) 0.43 PHB plus advance stop/yield (Zegeer et al. 2017a, b)	0.71 total crashes; 0.85 fatal, serious injury (Zegeer et al. 2017a, b)
LPI	0.41 to 0.95 range (Institute of Transportation Engineers 2004, Fayish and Gross 2010, Brunson et al. 2017)	Unknown/no CMFs available
Longer pedestrian phase	0.50 (CMF Clearinghouse citing Chen et al. 2014)	0.98 for all multi-vehicle crashes (Chen et al. 2013)
Protected crossing phase	0.61 urban intersections 0.49 Barnes Dance (CMF Clearinghouse citing Chen et al. 2014)	0.01 left-turn crashes for restricted left (Harkey et al. 2008); other CMFs also available

Source: NCHRP 893 Systemic Pedestrian Safety Analysis

Additional resources for selecting countermeasures are as follows:

- FHWA's Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations: Final Report and Recommended Guidelines
- NCHRP Synthesis 498: Application of Pedestrian Crossing Treatments for Streets and Highways

- Pedestrian and Bicycle Information Center's Evaluation of Pedestrian-Related Roadway Measures: A Summary of Available Research
- FHWA's PEDSAFE: Pedestrian Safety Countermeasure Selection System
- NCHRP Report 674: Crossing Solutions at Roundabouts and Channelized Turn Lanes for Pedestrians with Vision Disabilities
- TCRP 112/NCHRP 562: Improving Pedestrian Safety at Unsignalized Crossings
- Institute of Transportation Engineers' Designing Walkable Urban Thoroughfares: A Context Sensitive Approach
- FHWA's Crash Modification Factor Clearinghouse
- NHTSA's Countermeasures That Work
- FHWA's Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations

Step 6: Refine and Develop Projects to Implement

Step 6 involves considering developing a project, seeking additional community priorities, performing diagnostics, performing economic assessments or benefit-cost ratio evaluations (BCR), allocating funding, and implementing a systemic treatment plan, including construction of pedestrian safety improvements. These activities are dependent on an agency's project delivery process and procedures. Agencies are encouraged to contact their metropolitan planning organization or State Departments of Transportation for guidance on funding allocation and resources available.

As it relates to systemic safety considerations, Table 10 offers **a hypothetical example** for how to apply a cost-effectiveness index to a selection of 26 potential treatment sites, using model-derived SPFs and established CMF and countermeasure cost data. Site 1 represents the site with the highest predicted crash risk based on the SPF model, as indicated by the relatively high number of predicted crashes (A);
inversely, Site 3 represents the lowest risk site. The costs of implementation are NOT indicative of what the actual construction costs would be or that the countermeasures can be installed independent of any other design elements.

Table 10: Example cost-effectiveness analysis for different treatment scenarios

Site	Predicted No. of Crashes (A)	Countermeasure Options (B)	CMF (C)[a]	Countermeasure Cost per Site (D)[b]	Expected Crash Reduction if Treated (E) = A – (A x C)	Cost-Effectiveness Index (in thousands) (F) = D/E
1	3.6	High visibility crosswalk	0.63	$2,540	1.33	2
		Median island	0.69	$13,520	1.12	12
		High visibility crosswalk and median island	0.44[c]	$16,060	2.02	8
		PHB	0.53	$57,680	1.69	34

Site	Predicted No. of Crashes (A)	Countermeasure Options (B)	CMF (C)[a]	Countermeasure Cost per Site (D)[b]	Expected Crash Reduction if Treated (E) = A – (A x C)	Cost-Effectiveness Index (in thousands) (F) = D/E
2	1.36	High visibility crosswalk	0.63	$2,540	0.50	5
		Median island	0.69	$13,520	0.42	32
		High visibility crosswalk and median island	0.44	$16,060	0.76	21
		PHB	0.53	$57,680	0.64	19
3	0.45	High visibility crosswalk	0.63	$2,540	0.17	15
		Median island	0.69	$13,520	0.14	97
		High visibility crosswalk and median island	0.44	$16,060	0.25	64
		PHB	0.53	$57,680	0.21	273
Other 23 sites	18.51	High visibility crosswalk	0.63	$2,540	6.85	9
		Median island	0.69	$13,520	5.74	54
		High visibility crosswalk and median island	0.44	$16,060	10.37	36
		PHB	0.53	$57,680	8.70	152
All 26 sites	23.98	High visibility crosswalk	0.63	$2,540	8.87	7
		Median island	0.69	$13,520	7.43	47
		High visibility crosswalk and median island	0.44	$16,060	13.43	31
		PHB	0.53	$57,680	11.27	133

[a]CMFs provided here are the highest (most conservative) values.
[b]Average cost estimates are from *Costs for Pedestrian and Bicyclist Infrastructure Improvements*.
[c]Assuming multiplicative effects on crashes (0.63 x 0.69) for high visibility crosswalk and MI (multiply CMFs).
Source: NCHRP 893 Systemic Pedestrian Safety Analysis

Additional Resources for refining and implementing a treatment plan are as follows:

- FHWA's Systemic Safety Project Selection Tool
- NCHRP's ActiveTrans Prioritization Tool and NCHRP Report 803: Pedestrian and Bicycle Transportation Along Existing Roads—ActiveTrans Priority Tool Guidebook
- FHWA's CMFs in Practice, Introduction to Safety Performance Functions
- FHWA's CMFs in Practice, Quantifying Safety in the Roadway Safety Management Process
- AASHTO's Highway Safety Manual
- FHWA's Reliability of Safety Management Methods: Systemic Safety Programs
- FHWA's Guidebook for Developing Pedestrian and Bicycle Performance Measures

Step 7: Evaluate Program and Project Impacts

Step 7 involves evaluating project and program impacts before starting the process anew. Evaluation and monitoring is a key part of a systemic process and agencies may consider looking at various process measures to determine if the systemic analysis and prioritization process have been implemented as planned. The NCHRP guidebook outlines that the evaluation process can involve the following:

1. Determining if each of the other six steps in the process have been carried out;
2. Documenting what barriers to implementation arose and what additional measures are needed, such as data improvements, changes to policies or funding structures, training, additional tools, coordination across agencies, and so on; and
3. Summarizing how many locations in the system were identified as high risk and what percentage of the high-risk locations had specific countermeasures recommended and implemented through this process.

Evaluation of Systemic Projects:

Systemic projects are risk-based projects, with models used to predict baseline expected crash rates for facility and location. Given the low propensity for crashes at many sites, potential effects may be difficult to detect. Risk Identification and Evaluation can be facilitated by pooling roadway and project data across several jurisdictions, thereby increasing the potential for significant findings.

In the short term, alternative measures of impact may be assessed, such as operating speed, Leading Pedestrian Intervals. The NCHRP guidebook provides an example with the implementation of Leading Pedestrian Intervals at signalized intersections. The assessment of impacts would include the following:

1. Are pedestrians able to establish a presence in the crosswalk before motorists begin to turn?
2. Are conflicts reduced?
3. Do motorists STOP for pedestrians?
4. Are there certain locations where the treatment seems to work better than others?
5. How do these locations differ?

Additional Resources for evaluating program and project benefits are as follows:

- FHWA's How to Develop a Pedestrian and Bicycle Safety Action Plan
- National Association of City Transportation Officials' Urban Street Design Guide
- National Association of City Transportation Officials' Urban Bikeway Design Guide
- FHWA's Incorporating Safety into the Planning Process
- FHWA's Safety Focused Decision-Making Framework
- FHWA's Applying Safety Data and Analysis to Performance–Based Transportation Planning

Implementation

Systemic improvements could be developed under separate contracts. Data would be used to identify high risk locations on a certain timeframe cycle. Those locations could then be identified, and design contracts would be procured leading to construction. In the case of Highway Safety Improvement Program funds and due to the systemic approach, highway safety manual analyses may not be needed to justify the programming as they are data driven based on the high-risk locations determination while being included as an emphasis in the SHSP.

Prioritization: A checklist, developed by the agency specific for their needs, could be used to rank locations with the risk factors identified (Appendix A). The locations with the highest ranking and similar improvements would be grouped into systemic safety improvement projects.

Schedule

In situations where high crash locations are being addressed under other efforts, this approach could focus on the development and shelving of bid packages for the period of time and then continue with the same level of design while awarding construction contracts in later years. This could allow funding to be programmed and allow for replacement projects due to unforeseen delays to other projects. This could also be tied to the SHSP cycle where every five years, the data could be re-evaluated to determine high risk locations.

Evaluation

If included as part of a SHSP, crash reductions could be evaluated during an update to the plan and determine if this approach is effective.

Other resources

This guidance establishes potential focused systemic programs to reduce severe pedestrian crashes at intersection. The development of this guidance recognized funding limitations. A Technical Memorandum on funding and grant opportunities for MPOs and Capital Projects was developed to outline the funding that may be available for Department-led projects and local public agency projects to assist on the project planning and programming of funds.

Appendix A

Possible risk factors for pedestrians at intersections with relevant data sources

Factors	Measurement (Examples, Description)	Relevant Data Source (Examples, Description)
Roadway Functional Class	Arterial, Collectors, Local	Straight Line Diagrams (SLD) – Data gathering could be challenging for local roads
Roadway Volume	AADT	SLD, Count data (challenging for local roads)
Intersection Volume	TEV	Count data (challenging for local and county intersections)
Pedestrian Volume	Peak Hour	Count data (challenging for local and county intersections)
Vehicle Classification	Trucks, Buses	Count data (challenging for local and county intersections)
Area Type	Urban, Suburban, Rural, CBD	SLD (challenging for local roads)
Land Use	Residential, Commerial, Industrial, Mixed-use	Planning, Census data
Roadway/Corridor Characteristics	Cross section, slope/grade, condition of roadway, curbed/uncurbed,	SLD, As-built plans etc. (challenging for local roads)
Intersection Control	Signalized, Unsignalized	SLD, intersection inventory, Maintenance logs
Speed Limit		SLD (challenging for local roads)
Heavy Turn Volume		Count data (challenging for local and county intersections)
Median Type	No Median, Refuge Island, Island (no refuge)	SLD (challenging for local roads)
Number of Pedestrian Crashes		Crash Data, PD data (usually lags by couple of years, and could be challenging to gather data for local roads)
Crash Severity	Fatal, Injury	Crash Data, PD data (usually lags by couple of years, and could be challenging to gather data for local roads)
Nearby Transit Facility	Bus Stop, Transit Station, Park and Ride	SLD, Planning, Transit Schedules, etc.
Nearby School		Map data, plans
Nearby Walk Trip Generator	Park, Playground, Event venue, Parking Garage, Business, Hospital, Religious Site	Map data
School Zone		Map data
On-Street Parking		Map data, Municipal records
Population age groups/at Risk	Senior	Census

Factors	Measurement (Examples, Description)	Relevant Data Source (Examples, Description)
Distance to signalized intersection		SLD (challenging for local roads)
Roadway/Intersection Lighting		Electrical Plans
Presence of Pedestrian Facilities	Sidewalks, Crosswalks, Curb ramps ped signals)	Plans, As-builts, SLD
Crossing Distance		Maps, As-builts
Intersection Sight Distance		As-built plans, map data
Intersection Geometry	Skewed intersection	Maps, As-builts
Presence of Signs	Ped Crossing Signs, Warning Signs	Sign plans, maps, SLD
Community Concerns	Identified by community	Local Plans, documented concerns, PD
Driver Behavior/Compliance	Stopping for pedestrians	NJTR-1
Pedestrian Behavior	Jaywalking, Inattention	NJTR-1
Condition of existing pedestrian facilities	Narrow sidewalks, poor sidewalk and pavement markings, damaged or missing signs, sidewalk/ramp grade	Inventory (How often is the inventory collected)
Population income/car ownership/demographics		Census
Pedestrian impairment		User Requests
Weather	Flooding, Icing, Improper snow clearing	Emergency Operations, Traffic Operations, PD