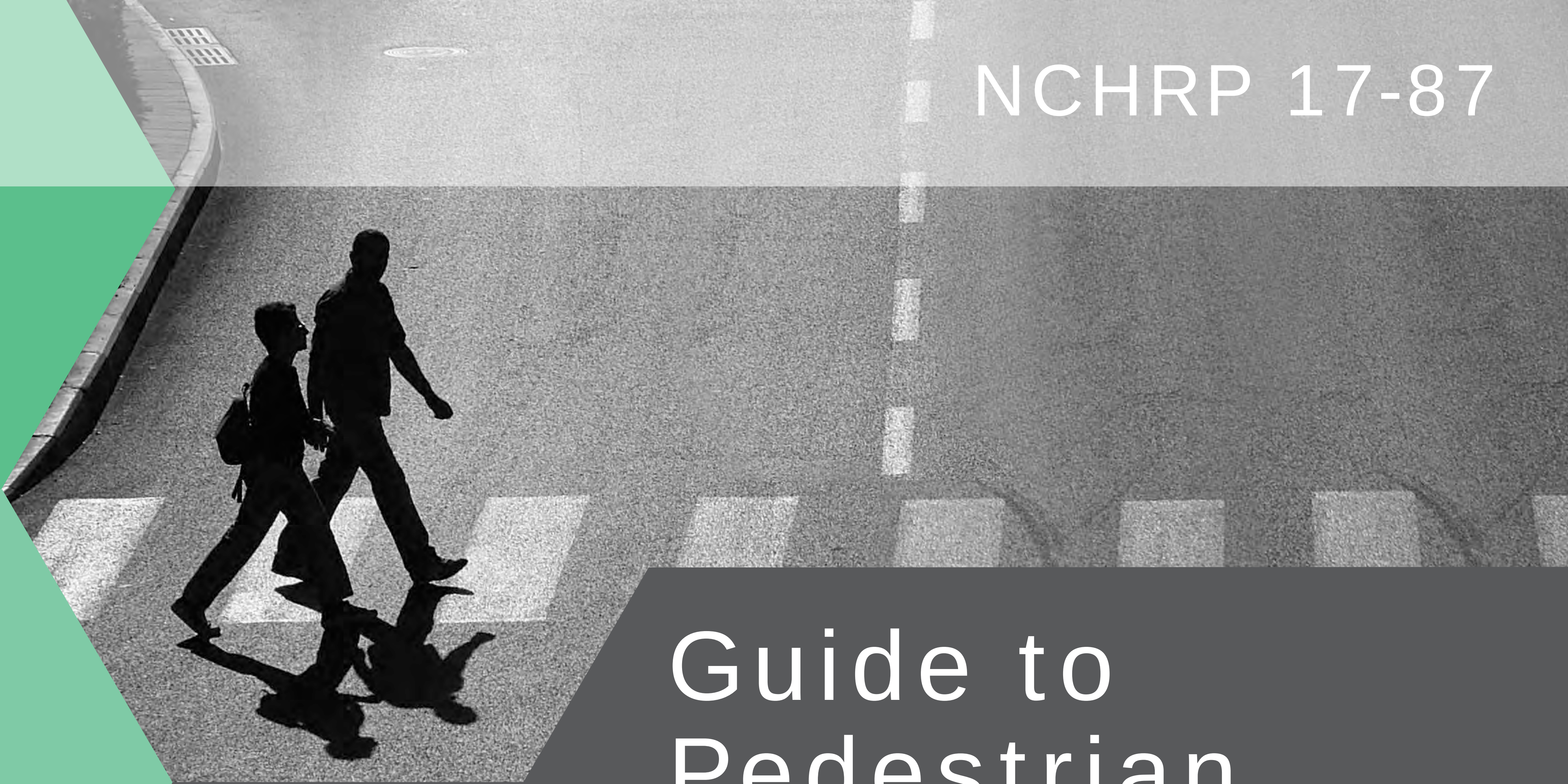


NCHRP 17-87

Guide to Pedestrian Analysis

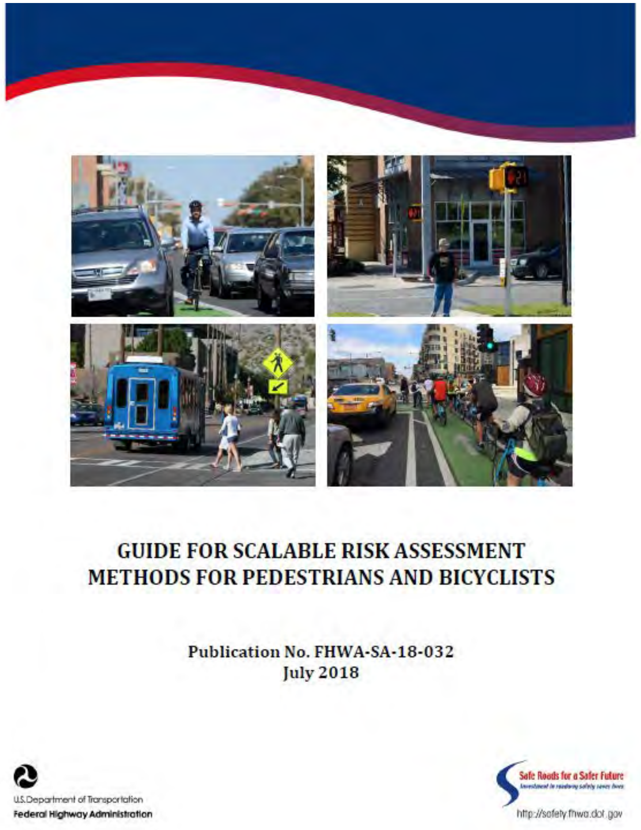
Pedestrian Safety Analysis

Roadmap

- Methods for estimating pedestrian exposure to crash risk
  - Potential applications of exposure data
- 3 approaches to identifying locations for pedestrian safety improvements
- Examples of pedestrian safety countermeasures
  - Methods for selecting countermeasures to address specific issues
- The association between selected countermeasures and pedestrians' perceived QOS using crossings

Pedestrian Exposure Estimation

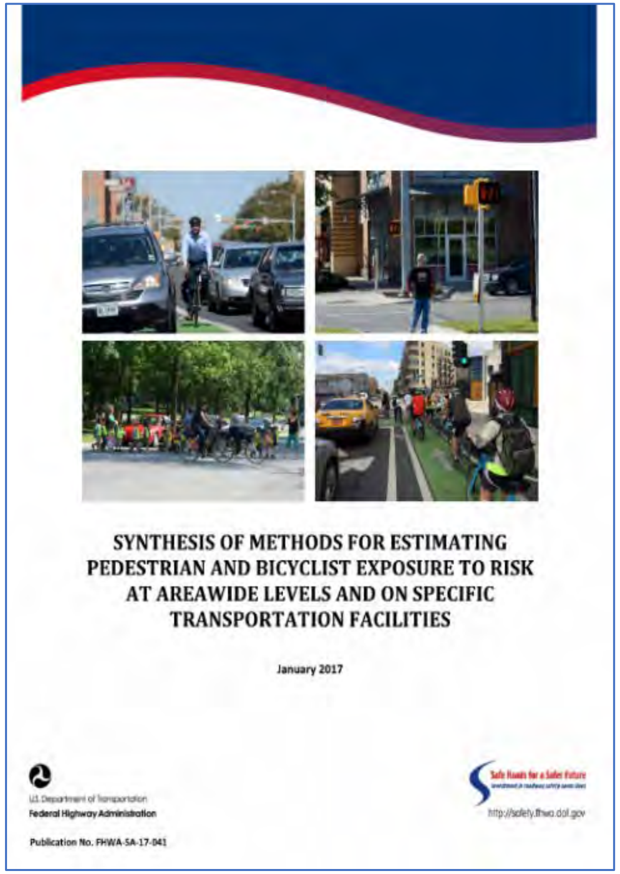
Exposure Estimation Resources


GUIDE FOR SCALABLE RISK ASSESSMENT METHODS FOR PEDESTRIANS AND BICYCLISTS

Publication No. FHWA-SA-18-032
July 2018

U.S. Department of Transportation
Federal Highway Administration

Safe Roads for a Safer Future
http://safety.fhwa.dot.gov


SYNTHESIS OF METHODS FOR ESTIMATING PEDESTRIAN AND BICYCLIST EXPOSURE TO RISK AT AREAWIDE LEVELS AND ON SPECIFIC TRANSPORTATION FACILITIES

January 2017

U.S. Department of Transportation
Federal Highway Administration

Safe Roads for a Safer Future
http://safety.fhwa.dot.gov

Publication No. FHWA-SA-17-041


ESTIMATING PEDESTRIAN ACCIDENT EXPOSURE

Final Report

TO 5211/6211

SafeTREC Safe Transportation Research & Education Center

(SafeTREC was formerly known as the Traffic Safety Center)

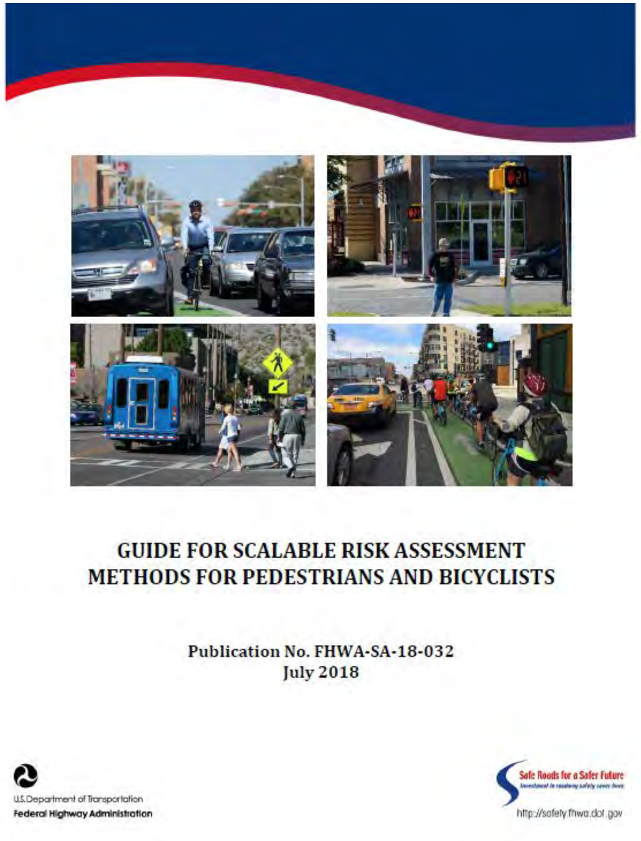
CALIFORNIA PATH

for

California State of California Department of Transportation (Caltrans)
Division of Research & Innovation

Defining “Exposure”

“A measure of the number of potential opportunities for a crash to occur.”



Categories of Exposure Measures

- **Population-based**—people or people who regularly walk in an area
- **Trip-based—# of** walking trips made in an area
- **Volume-based**—pedestrian or motorized traffic volume along a facility or crossing at an intersection
- **Distance-based**—total length traveled by pedestrians, e.g., along a facility or across a crossing
- **Time-based**—total time spent by persons while walking, e.g., person hours of travel along a facility or time to walk across a crossing

Table 3-1. Broad Categories of Exposure Definitions

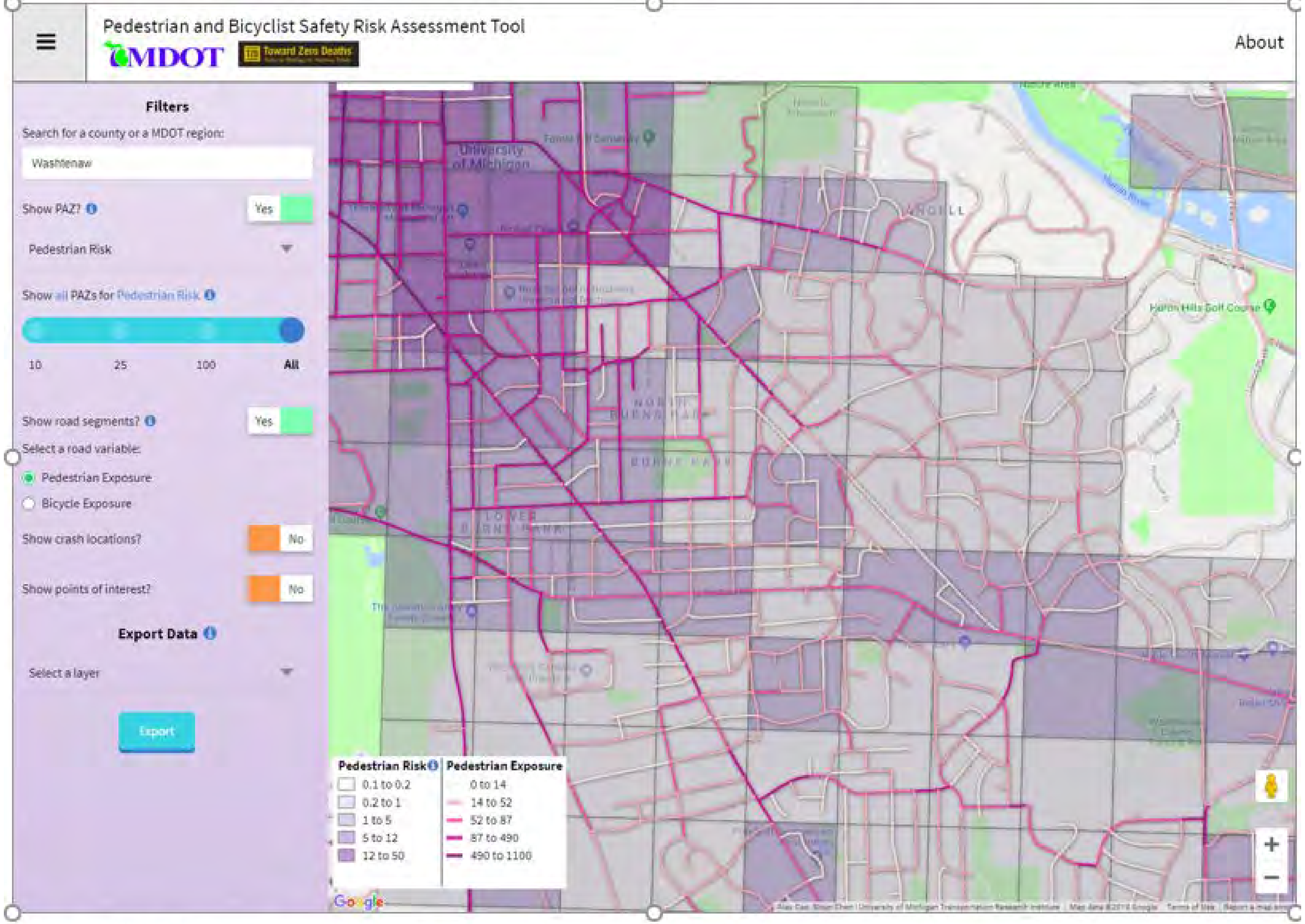
	Basis for Defining Exposure				
	Population	**Trips**	**Volumes**	**Distance**	**Time**
Appropriate Uses	▪ Areawide analysis, when detailed information about pedestrian activity is infeasible to collect	▪ Assessing pedestrian and bicyclist behavior in large areas; walking trip common characteristics ▪ Compare exposure at the areawide level, e.g., for a specific jurisdiction	▪ Estimating pedestrian volume and risk at a specific location ▪ Compare exposure at the micro level, i.e., for specific transportation facilities	▪ Estimating exposure at micro and macro level ▪ Estimating whether pedestrian risk increases with distance traveled ▪ Assessing how crossing distance affects risk	▪ Estimating exposure at micro and macro level ▪ Estimating whether pedestrian risk increases linearly with walking time ▪ Comparing risk between travel modes ▪ Comparing risk between different length crossings and individuals with different walking speeds
Data Sources	▪ American Community Survey (ACS): population by segment ▪ Travel demand surveys showing propensity to make walking trips on a regular basis	▪ Travel surveys	▪ Manual or automated counts	▪ Travel surveys ▪ Manual or automated counts of pedestrians, combined with the length of the specific area or corridor of interest	▪ Travel surveys ▪ Manual or automated counts of pedestrians and the measurement of the time traveled
Advantages	▪ Easy to obtain and low-cost; data available for most geographic regions ▪ Can adjust for differences in the underlying resident population of an area ▪ Vehicular volume likely to be related to area population ▪ Only way to represent exposure if no direct measurements are available	▪ Appropriate for use in large areas ▪ Best metric to assess relationship of walking with trip purpose ▪ Trips can be assessed as a function of person, household, and location attributes	▪ Relatively simple to collect as opposed to measures such as distance or time ▪ Data collection can be costly if done for longer durations ▪ Automated methods for counting are improving over time	▪ More information than manual or automated pedestrian counts alone ▪ Can be used to measure exposure at micro and macro level ▪ Common measure of vehicle exposure	▪ More information than manual or automated counts alone ▪ Can be used to measure exposure at micro and macro level ▪ Accounts for the traveler speed and different paths taken by the traveler to reach destination ▪ Allows for accurate comparison between travel modes
Dis-advantages	▪ Does not accurately represent levels of pedestrian activity ▪ Does not account for distance or time that pedestrians are exposed to traffic	▪ Does not accurately represent levels of pedestrian activity ▪ Does not provide enough detail needed to assess risk at specific locations ▪ Trip-based measures are not meaningful for facility-specific geographic scales	▪ Does not differentiate by walking speed, age, or other factors that may influence individual risk ▪ Does not account for time or distance walked ▪ Does not account for exposure over a macro level, i.e., city, county	▪ Relatively difficult to collect data ▪ Assumes risk is equal over distance traveled ▪ Does not account for traveler speed or different paths taken by the traveler	▪ Relatively difficult to collect data ▪ Assumes risk is equal over entire time travelling ▪ Time spent is overestimated ▪ Trips are underreported, i.e., short trips are usually forgotten by people
Common Measures	▪ Number of people in an area, potentially segmented by age, gender, race, socio-economic status, etc.; number of people in an area who walk regularly	▪ Number of trips, possibly by purpose	▪ Number of pedestrians per time period; number of people crossing; average daily, weekly, or annual pedestrian volume; product of pedestrian and vehicle volumes (interactions)	▪ Total or average miles traveled per pedestrian, total or average miles crossed per pedestrian	▪ Total or average amount of time spent traveling, total or average time taken by pedestrian crossing an intersection

Sources: Adapted from *Estimating Pedestrian Accident Exposure* (3) and *Guide for Scalable Risk Assessment Methods for Pedestrians and Bicycles* (2).

A Few Purposes of Estimating Exposure

- Develop pedestrian crash rates for a facility or geographic area
- Assess pedestrian safety trends over time and the effectiveness of safety countermeasures
- Assess crash rates based on metrics such as time of day, land use density, socioeconomic characteristics, gender, or facility type
- Conduct cost–benefit analyses of safety improvements
- Develop crash modification factors (CMFs) for safety countermeasures
- Develop safety performance functions (SPFs) for different vehicle-pedestrian crash and location types

Figure 3-2. Example of Michigan DOT's Pedestrian and Bicyclist Safety Risk Assessment Tool



Source: *MDOT Pedestrian and Bicyclist Safety Risk Assessment Tool* (*6*).

Exposure Scale and Coverage

Facility-specific	**Street crossing** (intersection or mid-block) *Example: The number of pedestrians crossing an intersection and the number of vehicles conflicting with pedestrians can be used to estimate exposure for each crossing movement.* **Road segment** (between intersections) *Example: The number of pedestrians crossing a mid-block location, where exposure is estimated based on crossing distance.*
Areawide	**Network** (traffic analysis zone, census tract, census block group) *Example: The number of pedestrian crashes in a census tract can be compared to the total population of the census tract.* **Regional** (city, county, metropolitan area, or state) *Example: The number of walking commuters or the number of pedestrian fatality rates per million population in a state.*

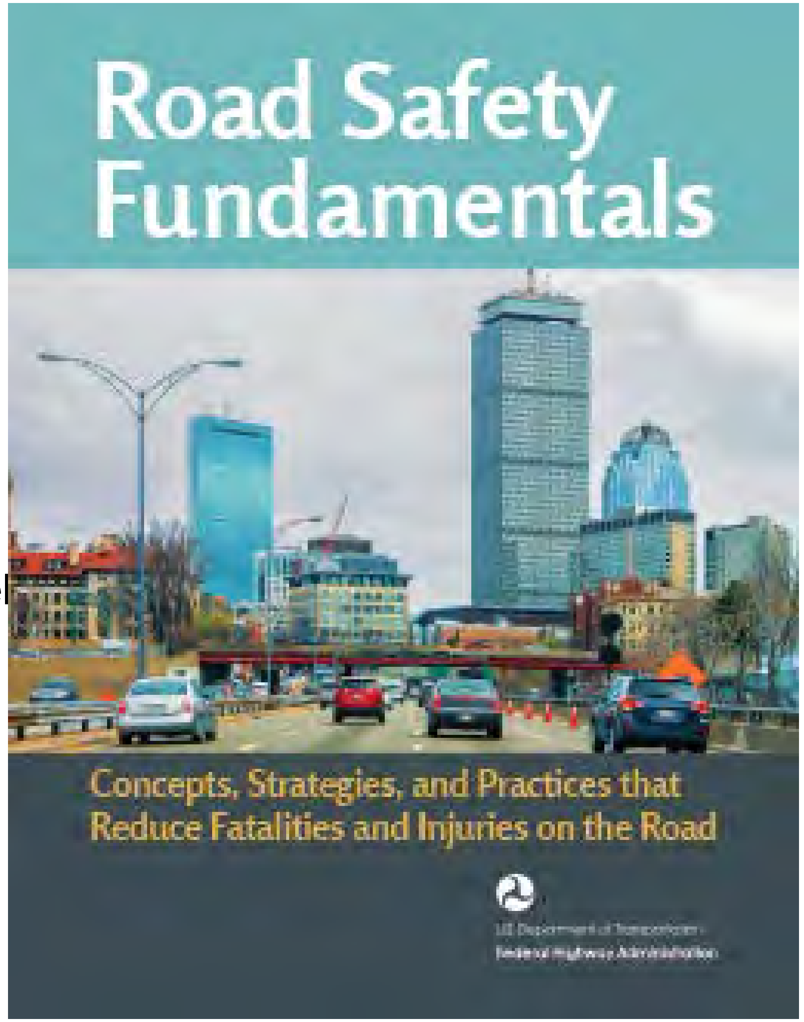
Typical Data Needs

Critical

- Vehicle–pedestrian crashes, including location, time, and severity
- Traffic volumes
- Some measure of pedestrian **exposure to crash risk**
- Road characteristics

Supplemental

- Traffic citation data (e.g., speeding, drivers failing to yield to crossing pedestrians)
- Vehicle–pedestrian conflicts and avoidance maneuvers
- Sight distance at intersections and driveways
- Injury surveillance and emergency medical systems data on pedestrian injury
- Law enforcement operations and observations data
- Public survey on perceptions of pedestrian safety
- Direct field observation data, including from pedestrian safety assessments or road safety audits
- Sociodemographic data (US Census), e.g., population and employment densities
- Travel behavior data (travel diaries and surveys including the National Household Travel Survey)
- Transit data (stop locations, boardings/alightings, routes)
- Infrastructure data
- Sidewalk and path locations
- Sidewalk physical and effective (i.e., usable) widths
- Sidewalk conditions
- Crosswalk dimensions
- Traffic signal timing for pedestrians
- Output from Walk Score or transportation demand models



Evaluating Countermeasure Impacts—Performance Measures

- **Crash frequency**—# of crashes occurring per year or other unit of time
- **Crash rates**—# of crashes normalized by a population or **metric of exposure**
  - E.g., # crashes per 100,000 people living in a city, per miles traveled or licensed drivers
  - Can be measured by the types of injuries sustained to the people involved in the crash (e.g., by injury severity)

Exposure Estimation Methodologies

Sketch Planning – Areawide Analysis

Sketch planning includes methods to estimate exposure that are simple to apply and provide an alternative to complex models. They may be implemented in a spreadsheet or geographic information system and incorporate travel survey data. The methods primarily depend on the available data (e.g., nationally collected survey data) and require little effort in terms of data collection and no specialized expertise. They typically use simple computations, rules of thumb, and population estimates.

References and Resources (to name a few): (*7–14*)

UNITS OF EXPOSURE

- Population
- Distance traveled
- Number of commuters who walk
- Number of persons who regularly make walking trips
- Time spent traveling

DATA SOURCES	National Household Travel Survey (NHTS) American Community Survey (ACS) Regional travel surveys
GEOGRAPHIC SCALE	City, county, metropolitan area, state, country
ADVANTAGES	▪ Utilizes data that are available ▪ Includes simple computations and estimations ▪ Creates simple and practical solutions ▪ Requires limited resources ▪ Does not require specialized expertise
DISADVANTAGES	▪ Relatively low accuracy ▪ Challenging to validate ▪ Mostly aggregated estimates
EXAMPLES	The National Association of City Transportation Officials (NACTO, *7*) used ACS data to assess the risk of injury or death to cyclists. The analysis was also conducted at a city level for a variety of locations in the United States. A study used regional household travel survey and crash data to estimate exposure based on the number of trips, distance traveled, and travel time. Injury rates were disaggregated based on location and demographic characteristics, e.g., density, gender and age (*12*).

Network Analysis Model – Specific Transportation Facilities

Network analysis models are much more complex than sketch planning models and are based on a pedestrian network representation. They typically use a four-step modeling approach for trip generation and distribution. Space Syntax is one of the most well-known examples of network analysis models and was first developed in the mid-1980s in London. These models are used to estimate volumes for specific facility types (e.g., street segments or intersections) over an entire area of interest, such as a neighborhood or city. Beginning with base data collection and ending with forecasting future pedestrian volumes based on network changes, there are seven steps to create a Space Syntax predictive model.

Reference and Resource: (*15*)

UNITS OF EXPOSURE	
	Average Annual Pedestrian Volume
DATA SOURCES	Manual counts Census data
GEOGRAPHIC SCALE	Point
ADVANTAGES	▪ Good detail ▪ Reasonable accuracy ▪ Limited data requirements ▪ Useful for estimating pedestrian flows along corridors ▪ Applied widely in Europe and Asia ▪ Appropriate to urban volume analysis
DISADVANTAGES	▪ Relatively unused in the United States ▪ Model must be calibrated with pedestrian counts ▪ Requires existing GIS data ▪ Must be submitted to sensitive test ▪ Process is not intuitive (does not follow traditional trip generation and distribution steps)
EXAMPLE	A study applied the Space Syntax Model to estimate pedestrian volumes at intersections in Oakland, California. The output volumes were then used in a safety analysis for the city's first pedestrian master plan (*15*).

Direct Demand Model – Specific Transportation Facilities

Direct demand models are among the most widely used tools for pedestrian volume estimation and modeling. These models are also used as primary tools to measure pedestrian exposure for safety analysis. These models are very similar to aggregate demand models, although the analysis is performed at a larger level in the aggregate models.

References and Resources: (*16–19*)

UNITS OF EXPOSURE

Weekly Crossing Pedestrian Volume, Million Pedestrians per Unit of Time, Pedestrian Volumes	100 Million Miles Traveled

DATA SOURCES	Manual counts Automated counts Population and land use data Crossing distances Vehicle average daily traffic
GEOGRAPHIC SCALE	Point, segment
ADVANTAGES	▪ Highly accurate ▪ Detailed ▪ Utilizes available data ▪ Limited sample size required
DISADVANTAGES	▪ Does not capture behavioral structure ▪ Not easily transferable
EXAMPLES	A study developed a Poisson log–linear regression model to estimate pedestrian counts at signalized intersections. The independent variables in the model included land use variables and the day characteristics. Using this model, the total number of pedestrian miles traveled were estimated, representing exposure (*18*). A study estimated a generalized linear regression model using number of lanes, area type, and sidewalk system as the independent variables. The dependent variable was the weekly pedestrian crossing volume, representing pedestrian exposure in safety analysis (*19*).

Discrete Choice Model – Specific Transportation Facilities

Discrete choice models utilize information about crossings and crossing behavior to model pedestrian crossing behavior. Crash risk exposure can be estimated for any location along a pedestrian trip where a pedestrian interacts with a vehicle (i.e., a location where a pedestrian is likely to cross). Thus, these discrete choice models are used to develop pedestrian behavior choice models for each location along an entire trip.

References and Resources: *(20, 21)*

UNITS OF EXPOSURE

Vehicle volume encountered while crossing, Product of vehicle volume and pedestrian volume (interactions)

DATA SOURCES	Manual counts Manual field surveys
GEOGRAPHIC SCALE	Segment
ADVANTAGES	▪ Detailed ▪ Highly accurate
DISADVANTAGES	▪ Relatively few studies ▪ Significant initial data requirements
EXAMPLES	A study developed a nested logit model for developing a hierarchical choice structure between junctions and mid-block crossings. The model included origins, destinations, traffic characteristics, and pedestrian facilities as independent variables (*20*).

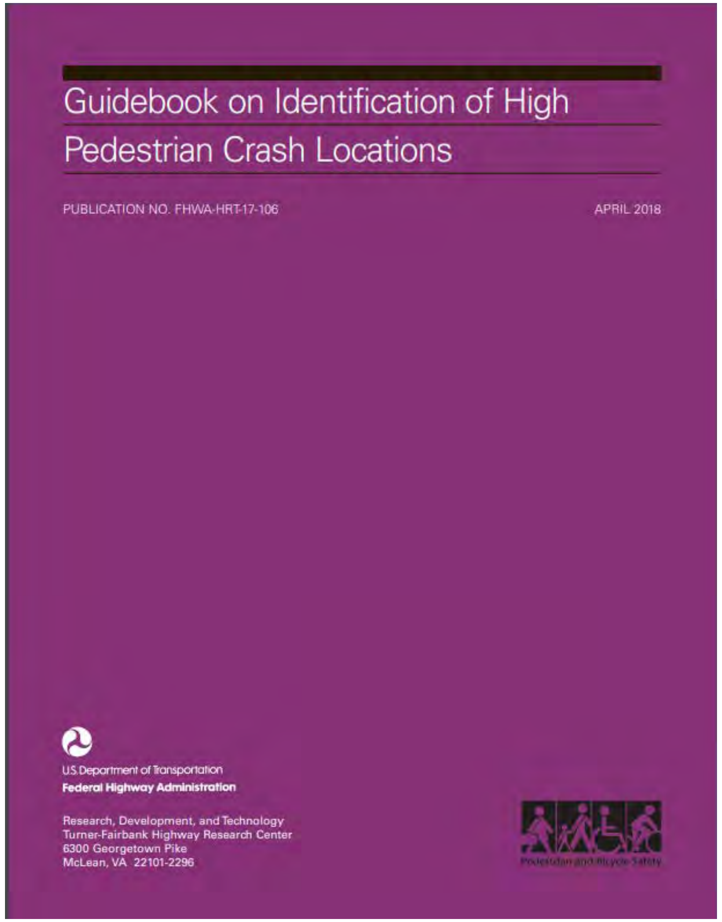
Treatment Location Identification

Approaches to Identify and Prioritize Locations for Safety Treatments

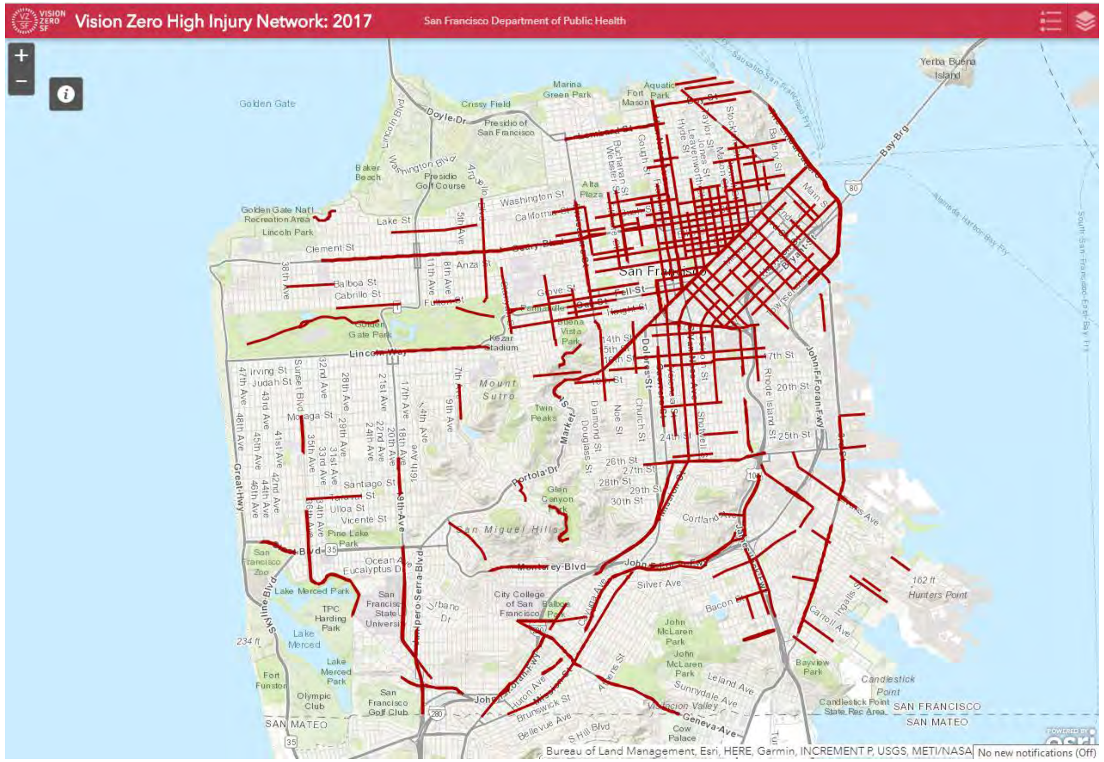
- **Crash-based (reactive)**—focusing on locations with high numbers or rates of crashes
- **Systemic (proactive)**—focusing on locations with similar characteristics with the greatest potential to prevent future crashes
- **Hybrid**—combining elements of both the crash-based and systemic approaches

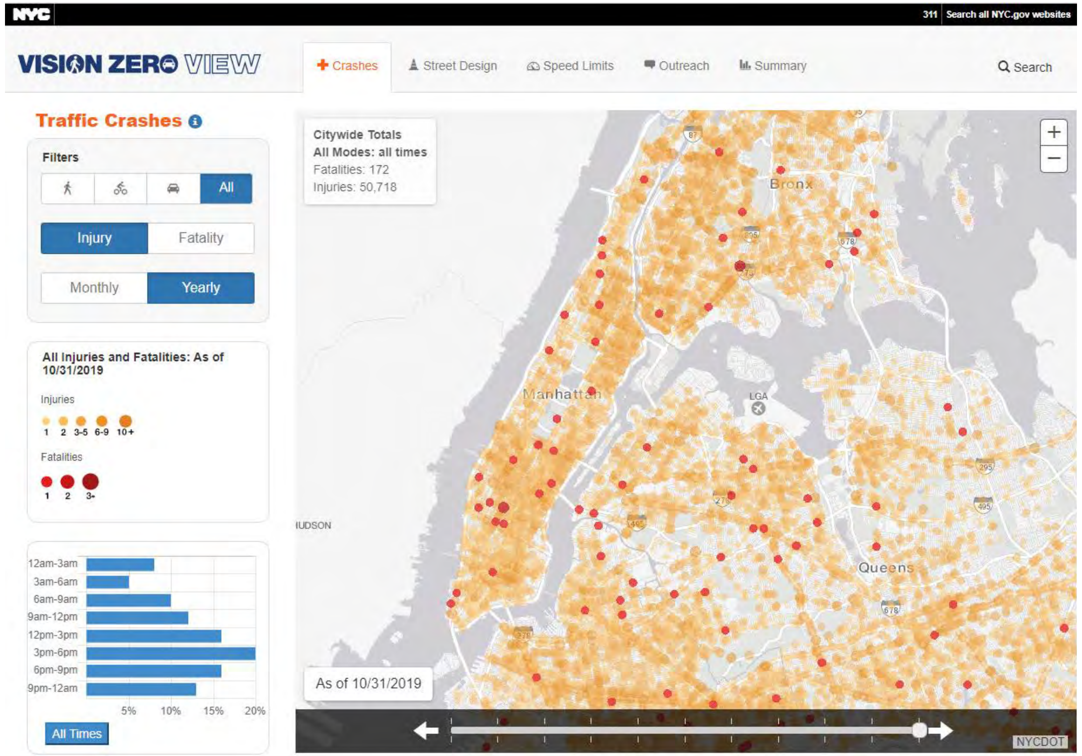
Crash-Based Approach

- Select Analysis Scale
- Select Performance Measures
- Select Screening Method
- Assign Crashes to Network Elements
- Prioritize Sites to Receive Treatment



Example Crash-Based Approaches





Systemic Approach

- Step 1: Define the Study Scope
- Step 2: Compile Data
- Step 3: Determine Risk Factors
- Step 4: Identify Treatment Sites
- Step 5: Select Potential Countermeasures
- Step 6: Refine and Implement Treatment Plan
- Step 7: Evaluate Program and Project Impacts

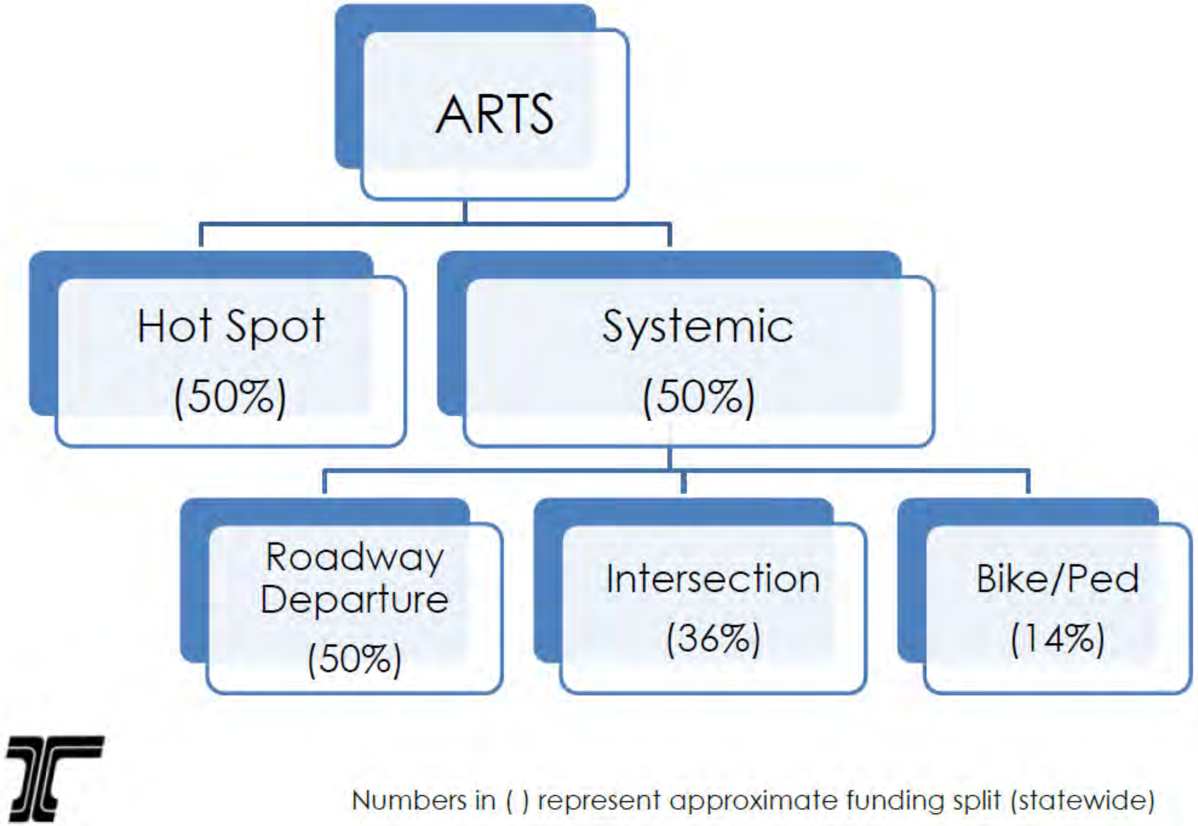
Figure 2. A systemic approach addresses sites with similar risk factors, regardless of crash history. The approach falls along a spectrum of other approaches to safety that are more or less proactive in treating sites based on risk or prior crash history.

Source: NCHRP Research Report 893: Systemic Pedestrian Safety Analysis

Hybrid Approach

Integrates the strengths of both the **crash-based** and **systemic approaches** to arrive at a prioritized list of treatment locations based upon:

- Historical crash patterns
- Clusters of risk factors



Oregon Department of Transportation's "All Roads Transportation Safety (ARTS) Program"

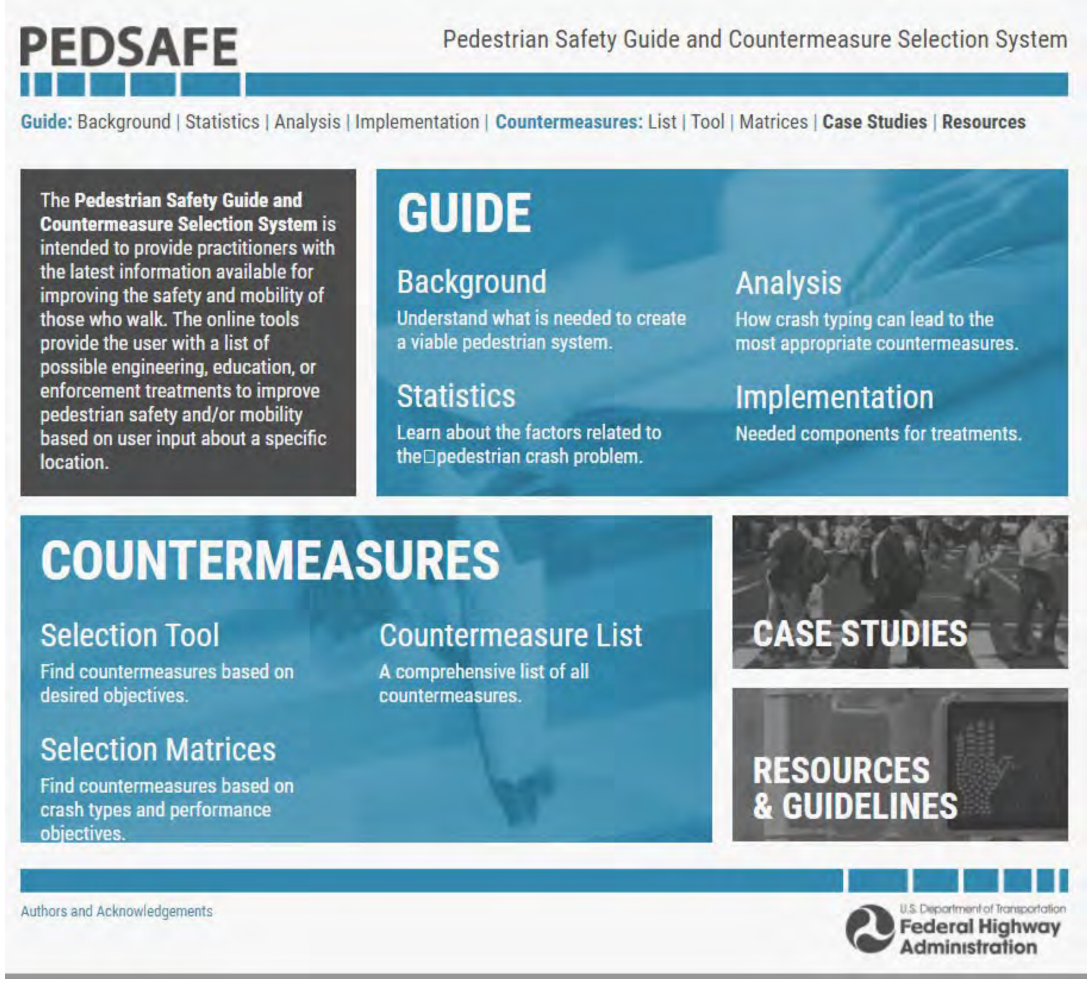
Source: oregon.gov/ODOT/HWY/TRAFFIC-ROADWAY/Pages/ARTS.aspx

Pedestrian Safety Countermeasure Selection

NCHRP 17-87: Guide to Pedestrian Analysis

Categories of Pedestrian Safety Countermeasures

- Along the roadway
- At crossing locations
- Transit access
- Roadway design
- Intersection design
- Traffic calming
- Traffic management
- Signs and signals



Selecting Countermeasures

For example, based upon:

- Posted speed limit and vehicle AADT
- Roadway configuration

Figure 3-3. Example Countermeasure Identification Matrix

Roadway Configuration	Posted Speed Limit and AADT								
	Vehicle AADT <9,000			Vehicle AADT 9,000–15,000			Vehicle AADT >15,000		
	≤30 mph	35 mph	≥40 mph	≤30 mph	35 mph	≥40 mph	≤30 mph	35 mph	≥40 mph
2 lanes (1 lane in each direction)	❶ 2 4 5 6	❶ 5 6 7 9	① 5 6 ❼ ❾	❶ 4 5 6	❶ 5 6 7 9	① 5 6 ❼ ❾	❶ 4 5 6 7 9	① 5 6 7 9	① 5 6 ❾
3 lanes with raised median (1 lane in each direction)	❶ 2 3 4 5	❶ ❸ 5 7 9	① ❸ 5 ❼ ❾	① 3 4 5 7 9	① ❸ 5 ❼ ❾	① ❸ 5 ❼ ❾	① ❸ 4 5 7 9	① ❸ 5 ❼ ❾	① ❸ 5 ❾
3 lanes w/o raised median (1 lane in each direction with a two-way left-turn lane)	❶ 2 3 4 5 6 7 9	❶ ❸ 5 6 7 9	① ❸ 5 6 ❾	① 3 4 5 6 7 9	① ❸ 5 6 ❼ ❾	① ❸ 5 6 ❾	① ❸ 4 5 6 7 9	① ❸ 5 6 ❾	① ❸ 5 6 ❾
4+ lanes with raised median (2 or more lanes in each direction)	❶ ❸ 5 7 8 9	❶ ❸ 5 7 8 9	① ❸ 5 8 ❾	① ❸ 5 7 8 9	① ❸ 5 ❼ 8 ❾	① ❸ 5 8 ❾	① ❸ 5 ❼ 8 ❾	① ❸ 5 8 ❾	① ❸ 5 8 ❾
4+ lanes w/o raised median (2 or more lanes in each direction)	❶ ❸ 5 6 7 8 9	① ❸ 5 ❻ 7 8 9	① ❸ 5 ❻ 8 ❾	① ❸ 5 ❻ 7 8 9	① ❸ 5 ❻ ❼ 8 ❾	① ❸ 5 ❻ 8 ❾	① ❸ 5 ❻ ❼ 8 ❾	① ❸ 5 ❻ 8 ❾	① ❸ 5 ❻ 8 ❾

Given the set of conditions in a cell,

- # Signifies that the countermeasure is a candidate treatment at a marked uncontrolled crossing location.
- ● Signifies that the countermeasure should always be considered, but not mandated or required, based upon engineering judgment at a marked uncontrolled crossing location.
- ○ Signifies that crosswalk visibility enhancements should always occur in conjunction with other identified countermeasures.*

The absence of a number signifies that the countermeasure is generally not an appropriate treatment, but exceptions may be considered following engineering judgment.

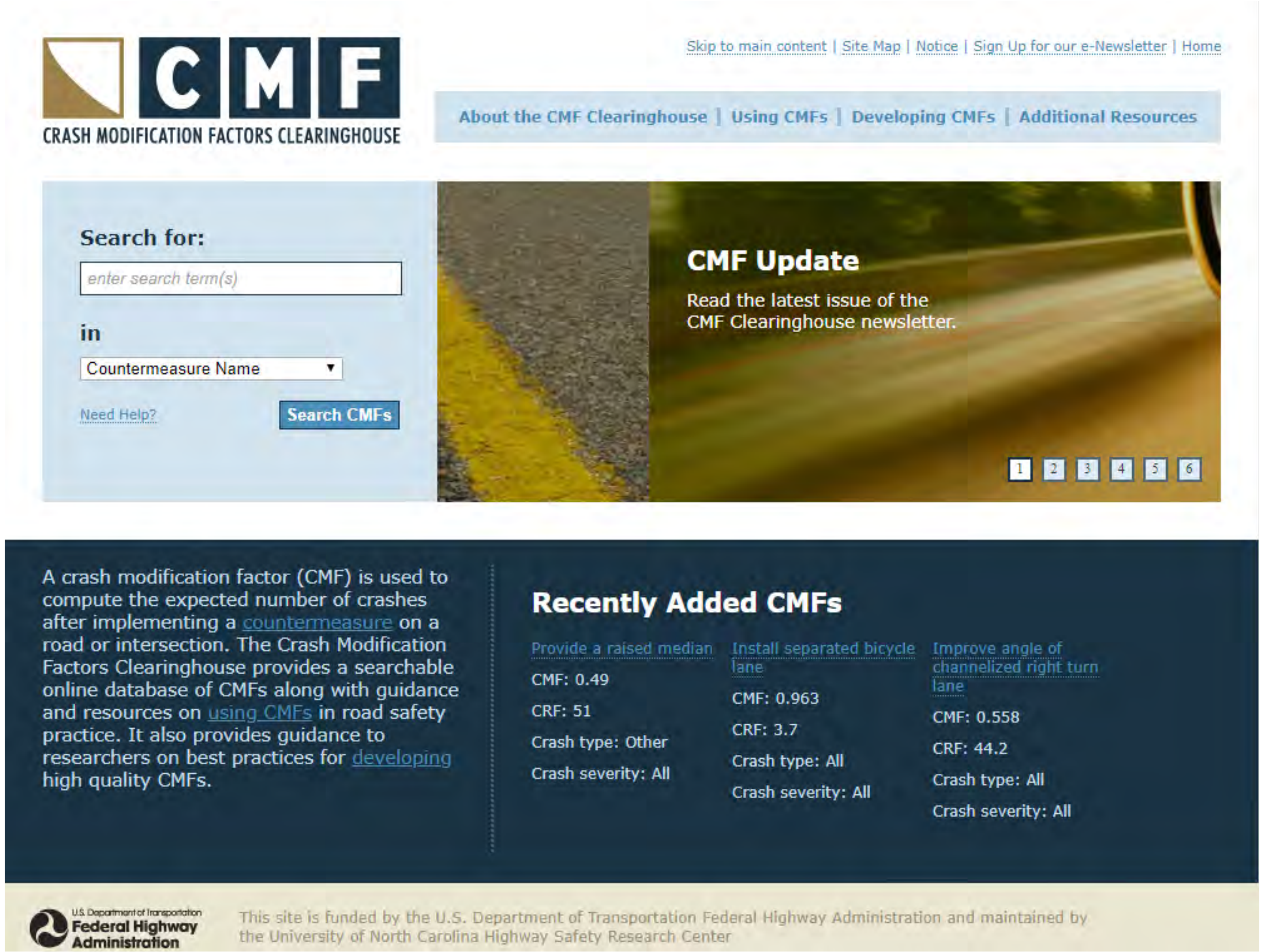
1 High-visibility crosswalk markings, parking restrictions on crosswalk approach, adequate nighttime lighting levels, and crossing warning signs
2 Raised crosswalk
3 Advance Yield Here To (Stop Here For) Pedestrians sign and yield (stop) line
4 In-Street Pedestrian Crossing sign
5 Curb extension
6 Pedestrian refuge island
7 Rectangular Rapid-Flashing Beacon (RRFB)**
8 Road Diet
9 Pedestrian Hybrid Beacon (PHB)**

Source: FWHA *Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations*

Selecting Countermeasures

For example, based upon:

- CMFs from the literature or Crash Modification Factors Clearinghouse—cmfclearinghouse.org



Pedestrian Safety Countermeasure Examples

NCHRP 17-87: Guide to Pedestrian Analysis

High-Visibility Crosswalk*

*countermeasure included in NCHRP 17-87 study

Countermeasure	CMFs or Other Estimated Pedestrian Safety Benefits	Example
High-visibility crosswalk—vertically arranged street markings designed to improve the visibility of the crosswalk compared to traverse parallel lines.	0.52 in urban locations (*30*) 0.63 for high visibility yellow/green markings in urban school zones (*31*) In both studies, the high-visibility markings replaced standard parallel markings.	 Source: Cambridge, MA; pedbikeimages.org

Raised Crosswalk

Countermeasure	CMFs or Other Estimated Pedestrian Safety Benefits	Example
Raised crosswalk/speed table—an elevated section of pavement with a marked crosswalk to encourage drivers to slow down.	0.55 (32) for areawide traffic calming	 Source: Cambridge, MA; pedbikeimages.org

Median Crossing (Refuge) Island
*countermeasure included in NCHRP 17-87 study

Countermeasure	CMFs or Other Estimated Pedestrian Safety Benefits	Example
Median crossing (refuge) island—a protected space placed in the center of the street to facilitate pedestrian crossings by allowing pedestrians to cross only one direction of traffic at a time.	0.68–0.71 (install raised median) (*33–35*)	 Source: Beverly Hills, CA; pedbikeimages.org

R1-6 Signs Gateway Treatment

Countermeasure	CMFs or Other Estimated Pedestrian Safety Benefits	Example
In-roadway YIELD TO PEDESTRIAN **sign (R1-6) installed as a gateway treatment**—R1-6 signs placed at a crosswalk along the edge of the road and on all lane lines, thus requiring drivers to slow down to drive between two signs.	No CMFs yet available. Motorist yielding has been highest with a gateway configuration (*35*). Speed reductions in some applications (*37, 38*).	 Source: Ann Arbor, MI; Michigan DOT

Pedestrian Hybrid Beacon (PHB)

Countermeasure	CMFs or Other Estimated Pedestrian Safety Benefits	Example
Pedestrian Hybrid Beacon (PHB) (HAWK signal)—a traffic control device used to stop motor vehicle traffic to allow pedestrians to cross safely.	0.31 (*39*) 0.45 (*33, 34*) 0.43 PHB plus advance stop or yield line (*33, 34*)	 Source: Phoenix, AZ; pedbikeimages.org

Leading Pedestrian Interval (LPI)

*countermeasure included in NCHRP 17-87 study

Countermeasure	CMFs or Other Estimated Pedestrian Safety Benefits	Example
Leading Pedestrian Interval (LPI)—provides pedestrians with a 3–7 second head start when entering an intersection, relative to the green signal for parallel vehicular traffic.	0.41–0.95 (*40–42*)	 Source: Seattle, WA; pedbikeimages.org

Rectangular Rapid-Flashing Beacon (RRFB)

*countermeasure included in NCHRP 17-87 study

Countermeasure	CMFs or Other Estimated Pedestrian Safety Benefits	Example
Rectangular Rapid-Flashing Beacon (RRFB)—user-actuated amber LED blocks that supplement warning signs at unsignalized intersections or mid-block crosswalks. They can be manually activated by pedestrians using a push button or can be passively activated by a pedestrian detection system.	0.53–0.64 (*33, 43*)	 Source: Davis, CA; pedbikeimages.org

Sidewalk

Countermeasure	CMFs or Other Estimated Pedestrian Safety Benefits	Example
Sidewalk—a paved path for pedestrians set along the side of a roadway.	0.26 (*44*)	 Source: Pittsford, NY; pedbikeimages.org

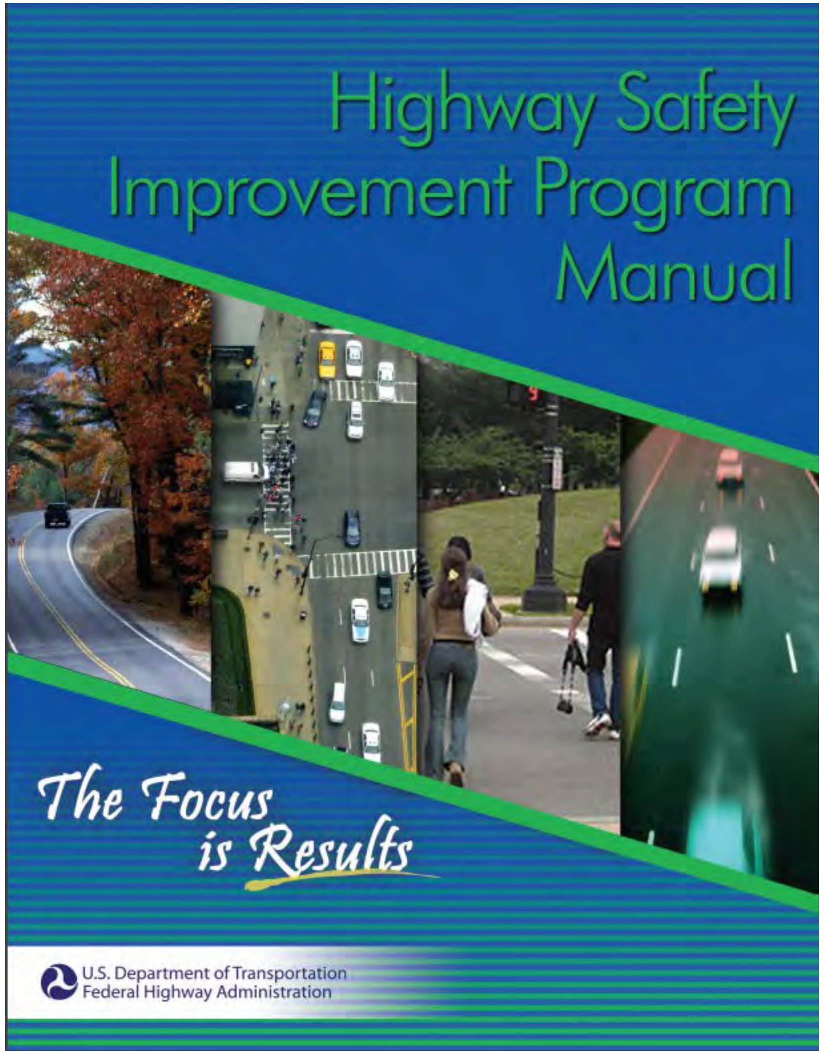
Matching Countermeasures to Risk Factors

Pedestrian safety risk is a composite of:

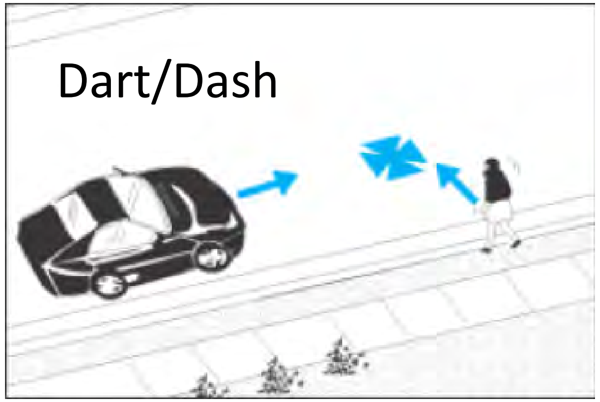
- **Crash-contributing factors**—elements of the environment, the persons involved in a crash, road user behaviors, etc. that may have played a contributing role in the crash
- **Crash types**—the sequence of road user movements that immediately lead up to the crash

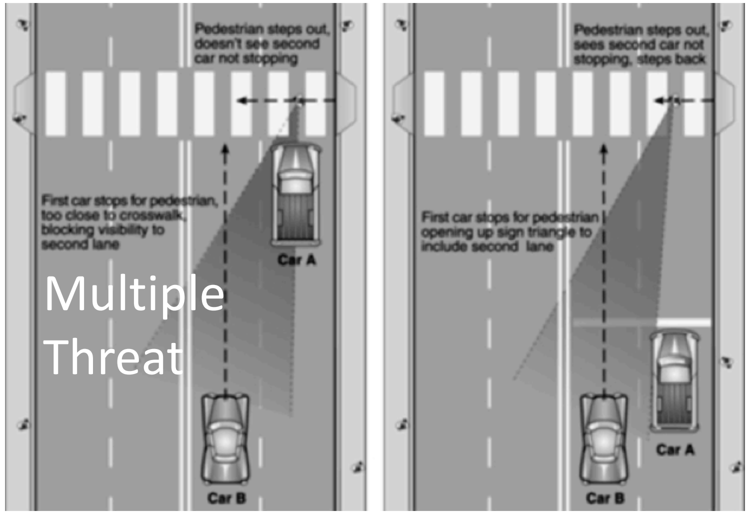
Pedestrian Crash-Contributing Factors

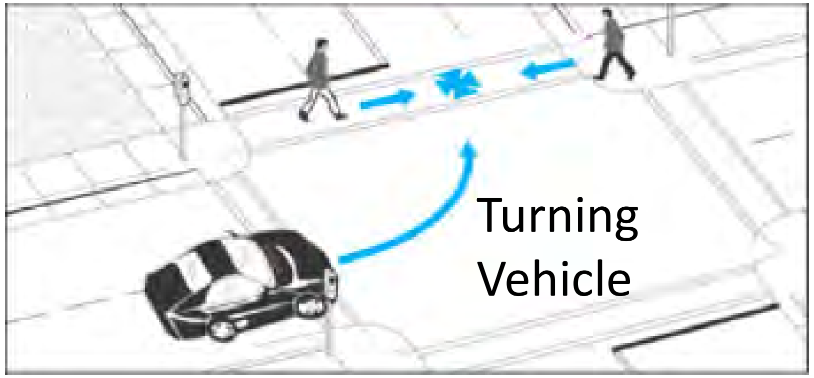
- Vehicle speed
- Driver and pedestrian compliance with regulations and traffic devices
- Pedestrian crossing behaviors
- Built environment or land use area type
- Intersection presence and types of traffic control devices
- Pedestrian crossing distance
- Time of day/day of week/seasonal factors
- Alcohol impairment on the part of pedestrians or drivers
- Demographics
- Special populations, such as school-aged children, older adults, and persons with disabilities
- Presence of transit stops



Pedestrian Crash Types







Source: pedbikesafe.org

Assessing Countermeasure Effectiveness

- Crash reduction
- Motorist yielding
- Pedestrian satisfaction

Crash Reduction

- **Crash-modification factors (CMFs)**—provide an estimate of a countermeasure’s ability to reduce certain types and severities of crashes following installation
- **Safety performance functions (SPFs)**—estimate the average number of crashes at a particular location based on certain characteristics present at the location (e.g., traffic volume, traffic speed)

Motorist Yielding

Table 3-2. Motorist Yielding Rates Associated with Different Crossing Treatments

Crossing Treatment	Sample Size (sites)	Motorist Yielding Rate (%)	
		Average	Range
No treatment (unmarked)	37	24	0–100
Crosswalk markings only (any type)	55	34	0–95
Crosswalk markings, plus:			
Pedestal-mounted flashing beacon	2	35	12–57
Overhead sign	6	37	0–52
Overhead flashing beacon (push-button activation)	14	51	13–91
Overhead flashing beacon (passive activation)	29	73	61–76
In-roadway warning lights	11	58	53–65
Median refuge island	21	60	0–100
Pedestrian crossing flags	6	74	72–80
In-street pedestrian crossing signs	17	74	35–88
Rectangular rapid-flashing beacon (RFFB)	42	79	45–100
School crossing guard	1	86	—
School crossing guard and RFFB	1	92	—
Pedestrian hybrid beacon (HAWK)	69	88	83–100
Mid-block crossing signals, half signals	6	98	96–100

Source: NCHRP Project 17-87 final report (*48*), compiling data from references (*48–65*).

Pedestrian Satisfaction—Uncontrolled Crossings

Marginal mean probability of satisfaction by countermeasure type (most to least):

- **Median islands with RFFBs**—0.739
- **Median islands**—0.667
- **Marked crosswalks**—0.497
- **Unmarked crosswalks**—0.294

N = 418. Controls: AADT, driver yielding, pedestrian slowed during crossing

Pedestrian Satisfaction—Signalized Crossings

Marginal mean probability of satisfaction by countermeasure type at signalized intersections:

- LPI—0.678
- Non-LPI—0.535

N = 418. Controls: AADT, driver yielding, pedestrian slowed during crossing

Other Research on Treatments

- **Road diet** (reducing number of vehicle through lanes): *moderately improves satisfaction* (*Elias, 2011; Choi, Sangyoup, Dongchan, Dongmin, & Sungkyu, 2016*).
- **Street lighting**: *moderately improves satisfaction* (*Bivina & Parida, 2019*)
- **Sidewalk with buffer from traffic**: *strongly improves satisfaction* (*Choi, Sangyoup, Dongchan, Dongmin, & Sungkyu, 2016: Zhao, Bian, Rong, Liu, & Shu, 2016*)

Countermeasure Effectiveness