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

NCHRP 17-87: Guide to Pedestrian Analysis
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
| NCHRP 17-87: Guide to Pedestrian Analysis |

### Table 3-1. Broad Categories of Exposure Definitions

<table>
<thead>
<tr>
<th>Basis for Defining Exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td><strong>Appropriate Uses</strong></td>
</tr>
<tr>
<td>- Areawide analysis, when detailed information about pedestrian activity is infeasible to collect</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Data Sources</strong></td>
</tr>
<tr>
<td>- American Community Survey (ACS): population by segment</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Advantages</strong></td>
</tr>
<tr>
<td>- Easy to obtain and low-cost; data available for most geographic regions</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Disadvantages</strong></td>
</tr>
<tr>
<td>- Does not accurately represent levels of pedestrian activity</td>
</tr>
<tr>
<td>- Does not account for distance or time that pedestrians are exposed to traffic</td>
</tr>
<tr>
<td>- Trip-based measures are not meaningful for facility-specific geographic scales</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Common Measures</strong></td>
</tr>
<tr>
<td>- 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</td>
</tr>
</tbody>
</table>

Sources: Adapted from *Estimating Pedestrian Accident Exposure* (5) 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

<table>
<thead>
<tr>
<th>Scale</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Facility-specific</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Street crossing</td>
<td>(intersection or mid-block)</td>
<td>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.</td>
</tr>
<tr>
<td>Road segment</td>
<td>(between intersections)</td>
<td>The number of pedestrians crossing a mid-block location, where exposure is estimated based on crossing distance.</td>
</tr>
<tr>
<td><strong>Area-wide</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Network</td>
<td>(traffic analysis zone, census tract, census block group)</td>
<td>The number of pedestrian crashes in a census tract can be compared to the total population of the census tract.</td>
</tr>
<tr>
<td>Regional</td>
<td>(city, county, metropolitan area, or state)</td>
<td>The number of walking commuters or the number of pedestrian fatality rates per million population in a state.</td>
</tr>
</tbody>
</table>
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)

## UNIT OF EXPOSURE

<table>
<thead>
<tr>
<th>Population</th>
<th>Distance traveled</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of commuters who walk</td>
<td>Time spent travelling</td>
</tr>
<tr>
<td>Number of persons who regularly make walking trips</td>
<td></td>
</tr>
</tbody>
</table>

## 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 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

<table>
<thead>
<tr>
<th><strong>Average Annual Pedestrian Volume</strong></th>
</tr>
</thead>
</table>

### 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: (18–19)

<table>
<thead>
<tr>
<th>UNITS OF EXPOSURE</th>
<th>Weekly Crossing Pedestrian Volume, Million Pedestrians per Unit of Time, Pedestrian Volumes</th>
<th>100 Million Miles Traveled</th>
</tr>
</thead>
<tbody>
<tr>
<td>DATA SOURCES</td>
<td>Manual counts</td>
<td>Automated counts</td>
</tr>
<tr>
<td></td>
<td>Population and land use data</td>
<td>Crossing distances</td>
</tr>
<tr>
<td></td>
<td>Vehicle average daily traffic</td>
<td></td>
</tr>
<tr>
<td>GEOGRAPHIC SCALE</td>
<td>Point, segment</td>
<td></td>
</tr>
<tr>
<td>ADVANTAGES</td>
<td>Highly accurate</td>
<td>Detailed</td>
</tr>
<tr>
<td></td>
<td>Utilizes available data</td>
<td>Limited sample size required</td>
</tr>
<tr>
<td>DISADVANTAGES</td>
<td>Does not capture behavioral structure</td>
<td>Not easily transferable</td>
</tr>
<tr>
<td>EXAMPLES</td>
<td>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).</td>
<td></td>
</tr>
<tr>
<td></td>
<td>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).</td>
<td></td>
</tr>
</tbody>
</table>
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)

<table>
<thead>
<tr>
<th>UNITS OF EXPOSURE</th>
<th>Vehicle volume encountered while crossing, Product of vehicle volume and pedestrian volume (interactions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DATA SOURCES</td>
<td>Manual counts</td>
</tr>
<tr>
<td></td>
<td>Manual field surveys</td>
</tr>
<tr>
<td>GEOGRAPHIC SCALE</td>
<td>Segment</td>
</tr>
<tr>
<td>ADVANTAGES</td>
<td>Detailed</td>
</tr>
<tr>
<td></td>
<td>Highly accurate</td>
</tr>
<tr>
<td>DISADVANTAGES</td>
<td>Relatively few studies</td>
</tr>
<tr>
<td></td>
<td>Significant initial data requirements</td>
</tr>
<tr>
<td>EXAMPLES</td>
<td>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).</td>
</tr>
</tbody>
</table>

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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
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
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

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
### High-Visibility Crosswalk*

*countermeasure included in NCHRP 17-87 study

<table>
<thead>
<tr>
<th>Countermeasure</th>
<th>CMFs or Other Estimated Pedestrian Safety Benefits</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High-visibility crosswalk</strong>—vertically arranged street markings designed to improve the visibility of the crosswalk compared to traverse parallel lines.</td>
<td>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.</td>
<td><img src="pedbikeimages.org" alt="Example Image" /></td>
</tr>
</tbody>
</table>

Source: Cambridge, MA; pedbikeimages.org
# Raised Crosswalk

<table>
<thead>
<tr>
<th>Countermeasure</th>
<th>CMFs or Other Estimated Pedestrian Safety Benefits</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raised crosswalk/speed table—an elevated section of pavement with a marked crosswalk to encourage drivers to slow down.</td>
<td>0.55 (32) for areawide traffic calming</td>
<td>![Raised Crosswalk Example](source: Cambridge, MA; pedbikeimages.org)</td>
</tr>
</tbody>
</table>
### Median Crossing (Refuge) Island

*countermeasure included in NCHRP 17-87 study*

<table>
<thead>
<tr>
<th>Countermeasure</th>
<th>CMFs or Other Estimated Pedestrian Safety Benefits</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Median crossing (refuge) island</strong>—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.</td>
<td>0.68–0.71 (install raised median) (33–35)</td>
<td><img src="pedbikeimages.org" alt="Example Image" /></td>
</tr>
</tbody>
</table>

Source: Beverly Hills, CA; pedbikeimages.org
### R1-6 Signs Gateway Treatment

<table>
<thead>
<tr>
<th>Countermeasure</th>
<th>CMFs or Other Estimated Pedestrian Safety Benefits</th>
<th>Example</th>
<th>Source: Ann Arbor, MI; Michigan DOT</th>
</tr>
</thead>
</table>
| **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). | ![Gateway Treatment Example](image) |                                   |
## Pedestrian Hybrid Beacon (PHB)

<table>
<thead>
<tr>
<th>Countermeasure</th>
<th>CMFs or Other Estimated Pedestrian Safety Benefits</th>
<th>Example</th>
</tr>
</thead>
</table>
| 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) | ![Image of PHB example](https://example.com) |

Source: Phoenix, AZ; pedbikeimages.org
Leading Pedestrian Interval (LPI) *countermeasure included in NCHRP 17-87 study

<table>
<thead>
<tr>
<th>Countermeasure</th>
<th>CMFs or Other Estimated Pedestrian Safety Benefits</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>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.</td>
<td>0.41–0.95 (40–42)</td>
<td>![Example Image](Seattle, WA; pedbikeimages.org)</td>
</tr>
</tbody>
</table>
## Rectangular Rapid-Flashing Beacon (RRFB)

*countermeasure included in NCHRP 17-87 study*

<table>
<thead>
<tr>
<th>Countermeasure</th>
<th>CMFs or Other Estimated Pedestrian Safety Benefits</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>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.</td>
<td>0.53–0.64 (33, 43)</td>
<td>![Example Image](Source: Davis, CA; pedbikeimages.org)</td>
</tr>
</tbody>
</table>

NCHRP 17-87: Guide to Pedestrian Analysis
## Sidewalk

<table>
<thead>
<tr>
<th>Countermeasure</th>
<th>CMFs or Other Estimated Pedestrian Safety Benefits</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sidewalk—a paved path for pedestrians set along the side of a roadway.</td>
<td>0.25 (44)</td>
<td><img src="pedbikeimages.org" alt="Sidewalk Image" /></td>
</tr>
</tbody>
</table>

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

- Dart/Dash
- Turning Vehicle
- Multiple Threat
- Walking Along Roadway
- Backing Vehicle

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

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

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

Reduce serious crashes
Increase driver yielding
Improve satisfaction