Practical Techniques for Improving Pedestrian Safety on Roadways

Instructor : Daniel Rodríguez Román
Location : Colegio de Ingenieros y Agrimensores de Puerto Rico, Casa Capitular de Mayagüez
Date : December 4, 2015
Outline

Part A. The Pedestrian Safety Problem

Part B. Network Screening and Pedestrian Problem Diagnosis

Part C. Pedestrian Safety Countermeasures and Countermeasure Selection

Part D. Design of Pedestrian Facilities and Case Studies
PART A.
THE PEDESTRIAN SAFETY PROBLEM
Overview of Part A

• Scope of the Pedestrian Safety Problem
  • Global Perspective
  • US Perspective
  • Puerto Rico Perspective

• Factors contributing to pedestrian crash occurrence and severity
Global Road Safety Statistics
Global Status of Road Safety

<table>
<thead>
<tr>
<th>1.24 millions deaths per year on world’s roads</th>
</tr>
</thead>
<tbody>
<tr>
<td>50% of deaths are of vulnerable road users</td>
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<tr>
<td>8th leading cause of death globally</td>
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<td>1st cause of death among 15-29 year-olds</td>
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<tr>
<td>15% increase in vehicles</td>
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<tr>
<td>88 countries with increasing road deaths</td>
</tr>
</tbody>
</table>

1.5 millions deaths per year due to HIV/AIDS

(WHO 2013a)
Global Status of Road Safety

• 80% of road traffic deaths occur in “middle-income” countries

(Source: WHO 2013a)
Road traffic deaths by type of road user, by WHO region

(Source: WHO 2013a)
In 2010, an estimated 273,000 pedestrians were killed in road traffic crashes.
Crash Injuries and Total Economic Costs

• Between 20 to 50 million injuries in 2010

• Global economic costs of crashes is estimated to be greater than $500 billion

• Road crashes consume around 1 to 2 percent of nations’ GDP

(WHO 2013a; Jacobs et al. 2000)
US Road Safety Statistics
2013 Traffic Fatalities by State and Percent Change from 2012

(Source: NHTSA 2015a)
Total Fatalities per 100,000 Population

States/Territories

US Average: 10.3

(NHTSA 2015a)
Total Fatalities per 100 Million VMT

State/Territory

US Average: 1.14

(NHTSA 2015a, FHWA 2014)
Crash Fatalities

Year

Total Facilities
Pedestrian Fatalities

(NHTSA 2015b)
Percent Change in Fatalities Relative to 2004 Values

Year

%Change Total Fatalities

%Change in Pedestrian Fatalities

(NHTSA 2015b)
Percent Change in Fatalities Relative to 2004 Values

Year | %Change Total Fatalities | %Change in Pedestrian Fatalities | %Change in VMT
-----|--------------------------|-------------------------------|-------------------
2004 | -30                      | -25                           | -20               
2005 | -20                      | -15                           | -10               
2006 | -10                      | -5                            | 0                 
2007 | 0                        | 5                             | 10                
2008 | 5                        | 15                             | 20                
2009 | 10                       | 25                             | 30                
2010 | 20                       | 30                             | 40                
2011 | 30                       | 40                             | 50                
2012 | 40                       | 50                             | 60                
2013 | 50                       | 60                             | 70                

(NHTSA 2015b)
Pedestrian Fatalities per 100,000 population

2013 Data

US Average: 1.5

(NHTSA 2015a)
Pedestrian Fatalities per 100,000 population

Population (thousands)

2013 Data

US Average: 1.5

(NHTSA 2015a)
Pedestrian Fatalities per 100 Million VMT

State/Territory

PR NV FL DC CA MT TX NM NJ GA PA OR MS MA IL KY CO MO SD VA ID KS OH IA NE WY

US Average: 0.147

(NHTSA 2015a, FHWA 2014)
Pedestrian injuries mostly concentrated in urban areas (Shinar 2007)

US Average: 14.4

(NHTSA 2015a)
Economic Cost of Traffic Crashes

• The total economic cost of traffic crashes in the US is estimated at $241,988,000,000

• The total societal cost of traffic crashes in the US is estimated at $835,793,000,000

• Injuries to pedestrians and bicyclist account for “7 percent of the economic costs and 10 percent of the societal harm”
  • Economic cost: $15,805,000,000
  • Societal cost: $86,559,000,000

(Blincoe et al. 2015)
Components of Total Economic Costs

- EMS: 0%
- Medical: 10%
- Market Productivity: 24%
- HH Prod: 8%
- Insurance: 8%
- Legal: 5%
- Congestion: 12%
- Prop. Damage: 31%
- Workplace: 2%

(Source: Blincoe et al. 2015)
Components of Comprehensive Costs

- Lost Quality of Life: 71%
- Medical: 3%
- EMS: 0%
- Market Productivity: 7%
- HH Prod: 2%
- Workplace: 1%
- Legal: 1%
- Congestion: 3%
- Prop. Damage: 9%

(Source: Blincoe et al. 2015)
Puerto Rico Road Safety Statistics
Puerto Rico’s Strategic Highway Safety Plan (SHSP)
Road Fatalities in Puerto Rico

(DTOP 2014)
Road Fatalities and Serious Injuries in Puerto Rico
Contributing Factors in Fatal Crashes

- Conducir Agresivamente: 43%
- Usuarios Vulnerables: 32%
- Conducir en Estado de Embriaguez: 28%
- Salirse de la Carretera: 25.5%
- Conductores Jóvenes (18-24 años): 25.4%
- Intersecciones: 13%
The Pedestrian Safety Problem in Puerto Rico

**2013**
- Conductores: 138, 40%
- Peatones: 44, 14%
- Pasajeros: 40, 12%
- Motociclistas: 6, 2%
- Ciclistas: 10, 3%
- Jinetes: 2, 1%
- Otros: 6, 2%

**2014**
- Conductores: 102, 34%
- Peatones: 94, 31%
- Pasajeros: 45, 15%
- Motociclistas: 12, 4%
- Ciclistas: 7, 2%
- Jinetes: 0, 0%
- Otros: 0, 0%

2013 vs 2014:
- Conductors: Decreased from 138 to 102 (34%)
- Pedestrians: Increased from 44 to 94 (31%)
- Bikers: Increased from 45 to 12 (15%)
- Other categories: Increased from 12 to 7 (4%)
The Pedestrian Safety Problem in Puerto Rico

January to August 2015

- Conductores: 69, 36%
- Peatones: 60, 32%
- Pasajeros: 26, 14%
- Motociclistas: 21, 11%
- Ciclistas: 8, 4%
- Jinetes: 0, 0%
- Otros: 6, 3%
PR’s SHSP

CONOCER TUS RESPONSABILIDADES
PUEDE SALVAR TU VIDA

• Mira a ambos lados antes de cruzar
• Utiliza los puentes y cruces identificados para peatones
• Utiliza las aceras y evita acercarte a las carreteras
• Donde no hay acera, camina de frente al tránsito
• Viste ropa clara en la noche
• No camines borracho por las vías públicas
Arranca campaña educativa para peatones y conductores

La campaña iniciará mañana
sábado, 20 de diciembre de 2014

Ya es hora de exigir compromiso al peatón

En el debate público hay un tema recurrente que es el del conductor temerario o el que está ebrio. Casi nunca se toma en cuenta el aspecto de los peatones, precisamente porque son ellos, junto con los ciclistas, el lado más vulnerable y que suele salir peor parado cuando se produce un accidente.
Comments or Questions?
Factors Contributing to Pedestrian Crashes
The Pedestrian

• May include people using devices such as:
  • Skateboards
  • Wheelchairs
  • Canes
  • Walkers
  • Motorized scooters
The Pedestrian

• Pedestrians are labeled as vulnerable road users, for obvious reasons:
  • Totally exposed, with no physical barrier to protect them from collisions
  • Huge mass difference between pedestrians and motorized vehicles

• The likelihood of a crashes resulting in serious or fatal injuries is greater for pedestrians than for vehicle occupants

• We are all pedestrians (well, nearly all of us)
  • The pedestrian group is highly heterogeneous, comprising of people from all ages, physical abilities, and cognitive capabilities

(Shinar 2007)
The Pedestrian

• The challenge is designing a roadway environment that is safe for pedestrians, given their vulnerabilities and heterogeneousness.

• Understanding human factors related to pedestrian safety will help us in:
  • Developing effective driver/pedestrian education campaigns
  • Selecting and designing effective countermeasures for improving road safety
Crash Contributing Factors

• Three general categories:
  • Human factors
  • Vehicle factors
  • Roadway/Environment factors

(From AASHTO 2010)
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<th>Pedestrian Crash Type Subgroup</th>
<th>Percent of Pedestrian Crashes</th>
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<td>Other intersection</td>
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<td>Vehicle turning at intersection</td>
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<td>Walking along roadway</td>
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<td>Intersection dash</td>
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<td>Working/playing in roadway</td>
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<td>Bus-related</td>
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(Source: Nabors et al. 2007)
Pedestrian Crossing Behavior of Adults

1. Approach Phase
   - Pedestrian visually monitors crossing decision elements (e.g. traffic signals in signalized intersections, approaching vehicles in non-signalize intersections)

2. Waiting Phase
   - Visual fixation mostly on vehicles

3. Crossing Phase
   - Looking straight ahead and fixation on danger zones

(Shinar 2007)
Pedestrian Crashes at Intersections and Non-Intersection Locations

• In the US, around 64 percent of pedestrian fatalities occur in non-intersection crossings

• In Puerto Rico, it appears that 87 percent of pedestrian fatalities occur in non-intersection crossings

(Source: Balk et al. 2014)
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<tr>
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(NHTSA 2015a)
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<th>Nonintersection</th>
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(NHTSA 2015a)
Factors Influencing Pedestrian Crossing at Unmarked Locations

• In most cases, pedestrians seek the shortest path

• It could be argued that pedestrian select the path with the lowest perceived disutility

• Factors influencing this selection can be grouped into two categories
  • Pedestrian Factors
  • Environmental Factors
Medellín, Colombia

• Existing problem

• Proposal

(Source: Wilmer Pipicano)
Pedestrian Factors

- Gender
- Age
- Alcohol consumption
- Self-identity
- Perceived control

(Balk et al. 2014)
Gender

• Male pedestrians are more likely to be involved in fatal crashes

• In 2013, US data shows that:
  • male pedestrian fatality rate was 2.09 per 100,000 males
  • female pedestrian fatality rate was 0.92 per 100,000 females
  • males accounted for 69 percent of pedestrian fatalities
  • males accounted for 56 percent of pedestrian injuries

• Possible explanations for rate difference:
  • difference in risk perception
  • males pedestrians are more likely to violate rules

(NHTSA 2015, Balk et al. 2014, Tom and Granie 2011)
Gender-Specific Pedestrian Fatality Statistics for Puerto Rico

• For the 2011-2013 period, males constitute 78 percent of pedestrian fatalities and 63 percent of pedestrian injuries

(PRTSC 2015, DTOP 2015)
## Age and Fatalities in the US

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<th>Age (Years)</th>
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<td>&gt;74</td>
<td>268</td>
<td>7,802</td>
<td>3.43</td>
<td>201</td>
<td>11,685</td>
<td>1.72</td>
<td>469</td>
<td>19,487</td>
</tr>
<tr>
<td>Unknown</td>
<td>24</td>
<td>*</td>
<td>*</td>
<td>7</td>
<td>*</td>
<td>*</td>
<td>34</td>
<td>*</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>3,247</strong></td>
<td><strong>155,652</strong></td>
<td><strong>2.09</strong></td>
<td><strong>1,482</strong></td>
<td><strong>160,477</strong></td>
<td><strong>0.92</strong></td>
<td><strong>4,735</strong></td>
<td><strong>316,129</strong></td>
</tr>
</tbody>
</table>

(NHTSA 2015)
## Age and Injuries in the US

<table>
<thead>
<tr>
<th>Age (Years)</th>
<th>Male</th>
<th></th>
<th></th>
<th>Female</th>
<th></th>
<th></th>
<th>Total</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Injured</td>
<td>Population (Thousands)</td>
<td>Rate</td>
<td>Injured</td>
<td>Population (Thousands)</td>
<td>Rate</td>
<td>Injured</td>
<td>Population (Thousands)</td>
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<tr>
<td>&lt;5</td>
<td>1,000</td>
<td>10,152</td>
<td>10</td>
<td>***</td>
<td>9,716</td>
<td>3</td>
<td>1,000</td>
<td>19,868</td>
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<tr>
<td>5-9</td>
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<td>10,509</td>
<td>17</td>
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<td>10,062</td>
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<td>3,000</td>
<td>20,571</td>
<td>14</td>
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<tr>
<td>10-15</td>
<td>4,000</td>
<td>12,674</td>
<td>35</td>
<td>3,000</td>
<td>12,123</td>
<td>24</td>
<td>7,000</td>
<td>24,798</td>
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<tr>
<td>16-20</td>
<td>4,000</td>
<td>11,014</td>
<td>41</td>
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<td>10,443</td>
<td>22</td>
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<td>21,457</td>
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<tr>
<td>21-24</td>
<td>4,000</td>
<td>9,389</td>
<td>45</td>
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<td>8,960</td>
<td>26</td>
<td>7,000</td>
<td>18,350</td>
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<tr>
<td>25-34</td>
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<td>21,641</td>
<td>28</td>
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<td>21,203</td>
<td>23</td>
<td>11,000</td>
<td>42,845</td>
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<td>35-44</td>
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<td>20,145</td>
<td>20</td>
<td>4,000</td>
<td>20,307</td>
<td>18</td>
<td>8,000</td>
<td>40,453</td>
<td>19</td>
</tr>
<tr>
<td>45-54</td>
<td>4,000</td>
<td>21,569</td>
<td>20</td>
<td>5,000</td>
<td>22,198</td>
<td>21</td>
<td>9,000</td>
<td>43,768</td>
<td>20</td>
</tr>
<tr>
<td>55-64</td>
<td>3,000</td>
<td>18,957</td>
<td>16</td>
<td>4,000</td>
<td>20,360</td>
<td>19</td>
<td>7,000</td>
<td>39,316</td>
<td>17</td>
</tr>
<tr>
<td>65-74</td>
<td>2,000</td>
<td>11,798</td>
<td>18</td>
<td>2,000</td>
<td>13,419</td>
<td>12</td>
<td>4,000</td>
<td>25,217</td>
<td>15</td>
</tr>
<tr>
<td>&gt;74</td>
<td>2,000</td>
<td>7,802</td>
<td>20</td>
<td>2,000</td>
<td>11,685</td>
<td>14</td>
<td>3,000</td>
<td>19,487</td>
<td>16</td>
</tr>
<tr>
<td>Total</td>
<td>37,000</td>
<td>155,652</td>
<td>24</td>
<td>29,000</td>
<td>160,477</td>
<td>18</td>
<td>66,000</td>
<td>316,129</td>
<td>21</td>
</tr>
</tbody>
</table>

(NHTSA 2015)
Data from New Zealand (1995)

(Source: Keall 1995)
Age

• In the US, **19 percent of all crash fatalities involved pedestrians over the age of 65** represent
  • Even though they constitute only **14 percent of the population**
  • **11 percent of injury crashes** involved pedestrians over the age of 65 represent
  • Data suggests that older pedestrians are conservative in their road crossing behavior

• **Children are the other major group of concern**
  • Children make risky road crossing decisions
  • Given their height, drivers might not see them

(NHTSA 2015, Balk et al. 2014)
<table>
<thead>
<tr>
<th>Age</th>
<th>Pedestrian Crash Contributing Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-9</td>
<td>Ran into street, ran from between parked vehicles, playing in street</td>
</tr>
<tr>
<td>10-14</td>
<td>Ran into street, ran from between parked vehicles, failed to obey signal, unsafe skateboard or rollerblade maneuvers, unsafe entering or exiting, safe movement violation</td>
</tr>
<tr>
<td>15-19</td>
<td>Failed to obey signal, unsafe skateboard maneuver, walking running in the wrong direction, leaning/clinging to vehicle</td>
</tr>
<tr>
<td>20-24</td>
<td>Alcohol impaired, walking/running in the wrong direction, talking/standing in the road, lying in the road</td>
</tr>
<tr>
<td>25-44</td>
<td>Alcohol impaired, working on car in parking lot, talking/standing in road, lying in road</td>
</tr>
<tr>
<td>45-64</td>
<td>Alcohol impaired, jaywalking, lack of conspicuity</td>
</tr>
<tr>
<td>65+</td>
<td>Jaywalking, stepped into street, failed to yield</td>
</tr>
</tbody>
</table>

(Shinar 2007)
Elderly Pedestrians

• Older pedestrians may have difficulty walking
  • Their route planning might involve the minimization of street crossing and the minimization of risk
  • In contrast, younger pedestrians might seek to minimize travel time (even to the point of performing illegal street crossings)

• It is hard to set walking speed standard for older pedestrians because many of them have medical conditions
  • Largest reductions in walking speed are due to illness, not age
Problems Associated with Elderly Pedestrians: Cognitive Deterioration

• Difficulty estimating time gaps in traffic
• Attention to near-side information only given problems in processing multiple sources of information at the same time
• Reduction in the level of awareness of their surrounding
  • Can result in them following the behavior of nearby pedestrians
• Delay in perceiving/recognizing dangers
• Confusion at complex junctions
• Failure in developing a crossing strategy

(van der Molen 2002, Shinar 2007)
Problems Associated with Elderly Pedestrians: Physical Deterioration

• Failure to see approaching vehicle
  • Eyesight problems (e.g., reduced contrast sensitivity)
  • Attention lapses

• Unable to see crossing signals because of the glare

• Unable to process relevant noise from traffic

• Crossing through unprotected sections of the road because crossing through controlled spot is too physically demanding

• Having perceived a collision danger, pedestrian might not have the physical capacity to maneuvering out of collision course

• Looking down while walking because of fear of falling

(van der Molen 2002, Shinar 2007)
• “From the perspective of the design engineer, the most important aspect of pedestrian behavior is the street crossing speed”

<table>
<thead>
<tr>
<th>Pedestrian Categories/Situations</th>
<th>Younger</th>
<th>Older</th>
</tr>
</thead>
<tbody>
<tr>
<td>All pedestrians</td>
<td>4.95</td>
<td>4.10</td>
</tr>
<tr>
<td>Males</td>
<td>5.12</td>
<td>4.30</td>
</tr>
<tr>
<td>Females</td>
<td>4.79</td>
<td>3.90</td>
</tr>
<tr>
<td>Narrow road (&lt;42 ft)</td>
<td>4.72</td>
<td>3.77</td>
</tr>
<tr>
<td>Wide road (&gt;50ft)</td>
<td>5.15</td>
<td>4.43</td>
</tr>
<tr>
<td>WALK signal at start of walk</td>
<td>4.79</td>
<td>3.94</td>
</tr>
<tr>
<td>DON’T WALK signal at start of walk</td>
<td>5.25</td>
<td>4.46</td>
</tr>
</tbody>
</table>

(Shinar 2007)
Child Pedestrians

• “Children differ with respect to the age at which certain abilities are fully developed”

• Proper training can help children develop fundamental pedestrian abilities at an earlier age than expected

• Having learned the ability with a trainer (e.g., mom, dad) does not imply that, when alone, the child will perform according to what she/he learned

(van der Molen 2002)
Children Abilities and Limitations

- Knowledge of traffic concepts and traffic rules
- Information processing speed
- Attention and distractibility
- Risk perception
- Insight into spatial relations around obstacles
- Gap acceptance
- Motor abilities

(van der Molen 2002)
Child Pedestrians: Risk Perception

• 5 year-olds can perceive and anticipate at least some risky traffic situation

• Children regard as dangerous sites with the presence of cars
  • But if no car is visible, they judge sites as safe

• Limited anticipation of danger

(van der Molen 2002)
Child Pedestrians: Risk Perception

• In busy streets, children generally stop and look in both directions

• In quiet streets, most children do not stop and look in both directions

• Large scale child education and training programs have been shown to be effective
  • Pedestrian skills training is as necessary as driver skills training

(van der Molen 2002)
<table>
<thead>
<tr>
<th>Function or ability</th>
<th>Presence of function or ability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&gt;85%</td>
</tr>
<tr>
<td>Peripheral vision</td>
<td>8 to 9</td>
</tr>
<tr>
<td>Movement perception</td>
<td>5</td>
</tr>
<tr>
<td>Color perception</td>
<td>4 to 5</td>
</tr>
<tr>
<td>Continuing visual search after a car passes by</td>
<td>5</td>
</tr>
<tr>
<td>Auditory perception/location</td>
<td>4 to 5</td>
</tr>
<tr>
<td>Insight in spatial relations</td>
<td>8 to 9</td>
</tr>
<tr>
<td>Choosing crossing site away from parked cars</td>
<td>10</td>
</tr>
<tr>
<td>Making a crossing decision in the presence of traffic</td>
<td>8</td>
</tr>
<tr>
<td>Distance estimation</td>
<td>8</td>
</tr>
<tr>
<td>Speed estimation</td>
<td>9 to 10</td>
</tr>
<tr>
<td>Perception and anticipation of risk</td>
<td>9 to 10</td>
</tr>
<tr>
<td>Identifying safe place to cross (without training)</td>
<td>10 to 12</td>
</tr>
<tr>
<td>Identifying safe place to cross (with training)</td>
<td>5</td>
</tr>
<tr>
<td>Stopping motor skill</td>
<td>5</td>
</tr>
</tbody>
</table>

(van der Molen 2002)
Predisposing Factors for Child Pedestrian Crashes

• Neighborhood characteristics
• Visual obstacles
  • “The percent of obstacle-related crashes generally peaks around age 3 to 5”
• Playing on or near the roadway
• Journey purpose
  • “Most studies indicate that school age children experience 25-33 percent of their accidents on their way to or from school”
• Stepping out of cars and buses
• Road types and vehicle intensity

(van der Molen 2002)
Child Crash Event Sequence

• Not stopping before crossing

• Not looking before crossing

• Dashing out into the road
Pedestrian Fatalities by Age Group in Puerto Rico (2011-2013)
Alcohol

• In the US, alcohol was a factor in 48 percent of crashes that resulted in pedestrian fatalities
  • 13 percent of drives had a blood alcohol concentration (BAC) of 0.08 percent by volume or greater
  • 35 percent of pedestrians had a BAC of 0.08 percent by volume or greater
  • In 6 percent of fatal crashes both the driver and the pedestrian had a BAC of 0.08 percent by volume or greater

(Balk et al. 2014)
Alcohol-Related Pedestrian Fatalities by Time-of-Day in PR
Factors Involved in Adult Pedestrian Crashes

- Alcohol
  - In many countries, drinking and walking is a major pedestrian-related problem
  - “Drinking and walking may be as common or even more common – and as severe a problem or more severe – than drinking and driving”
  - Drunk-driving campaigns might lead to increase in drunk-walking problems
  - Public not generally aware of risks associated with drinking and walking

- Inattention and distractions
  - Cell phone users
  - People listening to music
The effects of mobile phone use on pedestrian crossing behaviour at signalised and unsignalised intersections

Julie Hatfield *, Susanne Murphy

NSW Injury Risk Management Research Centre, The University of NSW, Sydney 2052, Australia
Received 2 May 2006; received in revised form 26 June 2006; accepted 4 July 2006

Abstract

Research amongst drivers suggests that pedestrians using mobile telephones may behave riskily while crossing the road, and casual observation suggests concerning levels of pedestrian mobile-use. An observational field survey of 270 females and 276 males was conducted to compare the safety of crossing behaviours for pedestrians using, versus not using, a mobile phone. Amongst females, pedestrians who crossed while talking on a mobile phone crossed more slowly, and were less likely to look at traffic before starting to cross, to wait for traffic to stop, or to look at traffic while crossing, compared to matched controls. For males, pedestrians who crossed while talking on a mobile phone crossed more slowly at unsignalised crossings. These effects suggest that talking on a mobile phone is associated with cognitive distraction that may undermine pedestrian safety. Messages explicitly suggesting techniques for avoiding mobile-use while road crossing may benefit pedestrian safety.

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Keywords: Distraction; Mobile telephones; Road safety; Pedestrians
Table 3
Percentage of observed pedestrians not using a mobile, talking on a mobile, and text messaging (SMS), who performed several “safe” crossing behaviours, amongst females and males (separately), at signalised crossings

<table>
<thead>
<tr>
<th></th>
<th>Not using</th>
<th>Talking</th>
<th>SMS</th>
<th>n</th>
<th>p</th>
<th>p (adj.)</th>
<th>p (cov.)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Females</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Started crossing on walk</td>
<td>83</td>
<td>97</td>
<td>100</td>
<td>108</td>
<td>.072</td>
<td>.106</td>
<td>.103</td>
</tr>
<tr>
<td>Looked at traffic before crossing</td>
<td>62</td>
<td>17</td>
<td>50</td>
<td>108</td>
<td>&lt;.001**</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Waited for traffic to stop before crossing (traffic present)</td>
<td>86</td>
<td>100</td>
<td>100</td>
<td>107</td>
<td>.036*</td>
<td>.035*</td>
<td>.998</td>
</tr>
<tr>
<td>Looked at traffic while crossing (traffic present)</td>
<td>29</td>
<td>7</td>
<td>33</td>
<td>107</td>
<td>.017*</td>
<td>N/A</td>
<td>.025*</td>
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<tr>
<td>Started at marked crossing</td>
<td>85</td>
<td>92</td>
<td>100</td>
<td>108</td>
<td>.247</td>
<td>.343</td>
<td>N/A</td>
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<tr>
<td>Finished at marked crossing</td>
<td>81</td>
<td>82</td>
<td>83</td>
<td>106</td>
<td>.851</td>
<td>N/A</td>
<td>N/A</td>
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<tr>
<td>Had no conflict experience</td>
<td>95</td>
<td>100</td>
<td>100</td>
<td>108</td>
<td>.214</td>
<td>.572</td>
<td>.998</td>
</tr>
<tr>
<td><strong>Males</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Started crossing on walk</td>
<td>73</td>
<td>58</td>
<td>78</td>
<td>119</td>
<td>.110</td>
<td>N/A</td>
<td>.372</td>
</tr>
<tr>
<td>Looked at traffic before crossing</td>
<td>60</td>
<td>63</td>
<td>67</td>
<td>119</td>
<td>.672</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Waited for traffic to stop before crossing (traffic present)</td>
<td>80</td>
<td>67</td>
<td>100</td>
<td>117</td>
<td>.121</td>
<td>N/A</td>
<td>.322</td>
</tr>
<tr>
<td>Looked at traffic while crossing (traffic present)</td>
<td>31</td>
<td>42</td>
<td>22</td>
<td>117</td>
<td>.275</td>
<td>N/A</td>
<td>.572</td>
</tr>
<tr>
<td>Started at marked crossing</td>
<td>82</td>
<td>86</td>
<td>78</td>
<td>117</td>
<td>.669</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Finished at marked crossing</td>
<td>71</td>
<td>59</td>
<td>78</td>
<td>114</td>
<td>.210</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Had no conflict experience</td>
<td>84</td>
<td>83</td>
<td>100</td>
<td>119</td>
<td>.912</td>
<td>N/A</td>
<td>.758</td>
</tr>
</tbody>
</table>

*p-Values (and n) are presented for the comparison between pedestrians not using a mobile and pedestrians talking on a mobile, unadjusted as well as adjusted (where applicable) for insufficient cell-size (p (adj.)) or inclusion of companions as a covariate (p (cov.)); * <.05, ** <.001.
Fig. 2. Mean crossing speed (m/s) at signalised crossings, by phone use and gender.
Self Identity and Perceived Control

• Self-identity refers to how the pedestrian thinks of himself/herself
  • Those pedestrians that view themselves as safe or careful pedestrians take fewer risks

• Perceived control: “The belief that one can determine one’s own internal states and behavior, influence one’s environment, and/or bring about desired outcomes” (Wallston et al. 1987)
  • Decreasing perceived control at unsafe areas could improve pedestrian safety
Handicap Pedestrians

- Image of handicapped person is usually of a person in a wheelchair

- Many types of disabilities
  - Visual and hearing impairments
  - Learning disabilities
  - Dyslexia
  - Illiteracy
Environmental Factors

• Trip Originators

• Trip Destinations

• Affordances
Trip Originators

• Origins of trips

• Some origins generate few pedestrian trips (e.g., homes), while others produce countless trips (e.g., shopping malls)

• Different types of trips origins could influence pedestrian flow behavior

(Balk et al. 2014)
Trip Destinations

• Where pedestrians are headed

• Destinations are often origins also

• Like in the case of trip origins, different types of trips destinations could influence pedestrian flow behavior
Affordances

• Refers to the qualities (real or perceived) of the environment

• Incorrectly perceived affordances lead to dangerous pedestrian behaviors
  • During the nighttime, pedestrians might overestimate the distance at which drivers can see them
  • Cleared spots in medians which encourage pedestrians crossing at unmarked areas

• Design of pedestrians environments should consider the perceived affordances created

(Balk et al. 2014)
Other Factors that Contribute to Occurrence of Pedestrian Crashes

• Factors that are related to relatively greater occurrence of crashes:
  • Greater proportion of uneducated populations
  
  • Presence of school and commercial areas
  
  • Some studies suggest that pedestrian crashes are more likely in low income areas
  
  • Likelihood of pedestrian crashes increases with road width

(Alluri et al. 2013)
Other Factors that Contribute to Greater Severity of Pedestrian Crashes

- Speed

- Weight and size of vehicles involved in crash

- Rain associated with greater crash severity (in Bangladeshi study)

(Alluri et al. 2013)
### Pedestrians Killed, by Related Factors

<table>
<thead>
<tr>
<th>Factors</th>
<th>Number</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Failure to yield right of way</td>
<td>1,181</td>
<td>24.9</td>
</tr>
<tr>
<td>In roadway improperly (standing, lying, working, playing)</td>
<td>744</td>
<td>15.7</td>
</tr>
<tr>
<td>Not visible (dark clothing, no lighting, etc.)</td>
<td>733</td>
<td>15.5</td>
</tr>
<tr>
<td>Improper crossing of roadway or intersection</td>
<td>686</td>
<td>14.5</td>
</tr>
<tr>
<td>Under the influence of alcohol, drugs, or medication</td>
<td>658</td>
<td>13.9</td>
</tr>
<tr>
<td>Darting or running into road</td>
<td>618</td>
<td>13.1</td>
</tr>
<tr>
<td>Failure to obey traffic signs, signals, or officer</td>
<td>175</td>
<td>3.7</td>
</tr>
<tr>
<td>Physical impairment</td>
<td>103</td>
<td>2.2</td>
</tr>
<tr>
<td>Inattentive (talking, eating, etc.)</td>
<td>99</td>
<td>2.1</td>
</tr>
<tr>
<td>Wrong-way walking</td>
<td>81</td>
<td>1.7</td>
</tr>
<tr>
<td>Traveling on prohibited trafficways</td>
<td>38</td>
<td>0.8</td>
</tr>
<tr>
<td>Emotional (e.g. depression, angry, disturbed)</td>
<td>37</td>
<td>0.8</td>
</tr>
<tr>
<td>Entering/exiting parked/standing vehicle</td>
<td>26</td>
<td>0.5</td>
</tr>
<tr>
<td>Vision obscured (by rain, snow, parked vehicle, sign, etc.)</td>
<td>19</td>
<td>0.4</td>
</tr>
<tr>
<td>Ill, blackout</td>
<td>12</td>
<td>0.3</td>
</tr>
<tr>
<td>Asleep or fatigued</td>
<td>5</td>
<td>0.1</td>
</tr>
<tr>
<td>Nonmotorist pushing vehicle</td>
<td>5</td>
<td>0.1</td>
</tr>
<tr>
<td>Portable electronics</td>
<td>4</td>
<td>0.1</td>
</tr>
<tr>
<td>Other factors</td>
<td>238</td>
<td>5.0</td>
</tr>
<tr>
<td>None reported</td>
<td>590</td>
<td>12.5</td>
</tr>
<tr>
<td>Unknown</td>
<td>702</td>
<td>14.8</td>
</tr>
<tr>
<td><strong>Total Pedestrians</strong></td>
<td><strong>4,735</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>
Factors of Special Interest for Puerto Rico

• Roadside businesses (“negocios ambulantes”)

• Topography

• Other factors?
Summary

• Puerto Rico appears to have a pedestrian safety problem

• Important factors related to pedestrian safety
  • Human factors
  • Roadway/environment factors
References


References


PART B.
NETWORK SCREENING AND PEDESTRIAN PROBLEM DIAGNOSIS
Overview of Part B

• Basic concepts related to the definition of roadway safety

• Procedures for identifying locations that represent a pedestrian safety problem
  • Crash data based methods
  • Surrogate measures

• Diagnosing pedestrian safety problem
  • Overview of diagnosis procedure
  • Road safety audits
A Proactive Approach to Pedestrian Safety

• The assessment and improvement of pedestrian road safety should be part of a proactive process

• Pedestrian safety considerations should be integral part of:
  • System-wide Road Safety Management Process
  • System-wide and project specific schedule of Road Safety Audits
Road Safety Management Process

Network Screening → Diagnosis → Countermeasures → Appraisal → Evaluation → Project Selection → Network Screening
Roadway Safety Fundamentals
What is safety?
• Traffic flow on Carr. 108?

• Traffic density on Carr. 108?

• Speed on Carr. 108?

• Safety of Carr. 108?
What is Safety?

• We can think of safety as a property of a **unit**

• A unit is may either be involved in a crash or a crash could occur on it

• Therefore, examples of units are:
  • Road segments
  • Intersections
  • Vehicles
  • People

(Hauer 2015)
Obviously, Crash Count ≠ Safety
• Crash counts are *random variables*

• Therefore, making decisions based on crash counts of a particular point in time may result in suboptimal decisions
  - *Beware of regression to the mean bias*
What is Safety (of a unit)?

• Its not precisely the count of accidents
  • Count of accidents is an indicator of a unit’s safety, but not precisely its safety

\[ E[\mu] \]

“The safety property of a unit is defined to be the number of accidents by type and severity, expected to occur on or to it in a specified period of time.”

(Hauer 1997, Hauer 2015)
“expected”

• In probability theory,

\[ E[\mu] \rightarrow \text{average in the long-run} \]

• In the context of road safety analysis,

\[ E[\mu] \rightarrow \text{“what the limit of the long-term average would be if it was possible to freeze all the safety-related traits and circumstances of the unit.” (Hauer 2015)} \]
Crash count for intersection X

Year


$E[\mu]$
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total fatalidades</td>
<td>344</td>
<td>&lt; 300</td>
</tr>
<tr>
<td>Promedio (&quot;moving average&quot;) de 5 años del total de fatalidades</td>
<td>355</td>
<td>318</td>
</tr>
<tr>
<td>Promedio (&quot;moving average&quot;) de 5 años del total de heridos graves</td>
<td>6,091</td>
<td>5,456</td>
</tr>
<tr>
<td>Promedio (&quot;moving average&quot;) de 5 años de la razón de fatalidades</td>
<td>1.93</td>
<td>1.85</td>
</tr>
<tr>
<td>Promedio (&quot;moving average&quot;) de 5 años de la razón de heridos graves</td>
<td>33.02</td>
<td>31.70</td>
</tr>
</tbody>
</table>

(Source: DTOP 2014)
“by type and severity”

• What is the implication of the statement “by type and severity”?
  • Usually, a single number if not enough to characterize a unit’s safety
  • The safety of a unit is a collection of numbers (safety vector, safety array?)

• Example (Hauer 2015):

<table>
<thead>
<tr>
<th>Accident type</th>
<th>PDO</th>
<th>Injury</th>
<th>Fatal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rear-end</td>
<td>3.10</td>
<td>1.70</td>
<td>0.20</td>
</tr>
<tr>
<td>Angle</td>
<td>1.40</td>
<td>0.90</td>
<td>0.10</td>
</tr>
<tr>
<td>Single-vehicle</td>
<td>0.30</td>
<td>0.10</td>
<td>0.02</td>
</tr>
<tr>
<td>Pedestrian</td>
<td></td>
<td>0.05</td>
<td>0.03</td>
</tr>
</tbody>
</table>

(Hauer 2015)
Safety as People’s Subjective Perception

• Safety as a feeling that may not align with an objective, quantifiable measure related to safety

• Example:
  • Lines painted for pedestrian crosswalks
  • Pedestrian may feel that it is safer to cross
  • The reality might be that nothing have changed
  • Feeling more safe, pedestrians might be less cautious

• Hauer (1997) calls “people’s subjective perception of safety as the feeling of security”.

(Hauer 1997)
(Adapted from Hauer 1997)

Objective Safety

Subjective Safety (Security)

Ideal

A

A'

B

B'

C

C'

Markings

Fiasco

Propaganda
Back to the objective view of safety...

Safety is the **expected crash frequency** of a unit

\[
\text{Crash Frequency} = \frac{\text{number of crashes on unit}}{\text{unit of time}}
\]

\[
E \left[ \frac{\text{number of crashes on unit}}{\text{unit of time}} \right] = E[\text{Crash Frequency}]
\]

(Hauer 1997)
Network Screening: Searching for Hazardous Locations
Road Safety Management Process

- Network Screening
- Diagnosis
- Countermeasures
- Appraisal
- Project Selection
- Evaluation
What is Network Screening?

• The identification of crash hotspots, hazardous road locations, high-risk locations, accident-prone locations, black spots, sites with promise, and priority identification locations in a road network

(Montella 2010)
What is Network Screening?

• The identification of crash hotspots in a road network

• HSM defined network screening as:
  • Reviewing a transportation network to identify and rank sites based on the potential for reducing average crash frequency.

(Montella 2010)
A Challenge in Network Screening

- Limited resources available for road safety
- Flawed analysis can result in:
  - False positives
    - Relatively safe sites identified as dangerous
  - False negatives
    - Relatively hazardous locations identified as safe

\[ E[\mu] \xrightarrow{\text{Unobserved}} \xrightarrow{\text{It has to be estimated!}} \]

Possible culprit? Regression-towards-the-mean bias

May result in waste of money and loss of lives
Screening for Pedestrian Crash Hotspots

• We will discuss two types of procedures:
  • Procedures based on crash data
    • Methods found in the Highway Safety Manual
    • Other methods
  • Procedures based on surrogate measures
Highway Safety Manual

Part A - Introduction, Human Factors, and Fundamentals
- Chapter 1 – Introduction and Overview
- Chapter 2 – Human Factors
- Chapter 3 - Fundamentals

Part B - Roadway Safety Management Process
- Chapter 4 – Network Screening
- Chapter 5 – Diagnosis
- Chapter 6 – Select Countermeasures
- Chapter 7 – Economic Appraisal
- Chapter 8 – Prioritize Projects
- Chapter 9 – Safety Effectiveness Evaluation

Part C - Predictive Method
- Chapter 10 – Rural Two-Lane Roads
- Chapter 11 – Rural Multilane Highways
- Chapter 12 – Urban and Suburban Arterials

Part D - Crash Modification Factors
- Chapter 13 – Roadway Segments
- Chapter 14 – Intersections
- Chapter 15 – Interchanges
- Chapter 16 – Special Facilities
- Chapter 17 – Road Networks

(Source: AASHTO)
Methods Described in the HSM (Performance Measures)

- Average crash frequency
- Crash rate
- EPDO average crash frequency
- Relative severity index
- Critical rate
- Excess predicted average crash frequency using method of moments
- Probability of specific crash types exceeding threshold proportion
- Excess proportion of specific crash types
- Level of service of safety
- Excess predicted average crash frequency using SPFs
- Expected average crash frequency with EB adjustment
- EPDO average crash frequency with EB adjustment
- Excess expected average crash frequency with EB adjustment

EPDO: equivalent property damage only
EB: empirical Bayes
SPF: safety performance function

(AASHTO 2009)
Average Crash Frequency (CF)

• Data requirement:
  • Crash data by location

• Formula:
  \[ CF = \frac{Number\ of\ Crashes}{Time\ Period} \]

• Procedure:
  • Determine the CF for all locations, and rank them accordingly

(AASHTO 2009)
Crash Rates (R)

• Data requirements:
  • Crash data
  • Traffic volume

• Formula:

\[ R_{\text{intersections}} = \frac{CF}{MEV} \]
\[ R_{\text{segments}} = \frac{CF}{VMT} \]

• Procedure:
  • Determine the R for all locations, and rank them accordingly
MEV and VMT

• For intersections, the measure of exposure commonly used is millions of entering vehicles

\[
MEV = 365 \times n \times \left( \frac{TEV}{10^6} \right)
\]

- TEV: total entering vehicles
- n: number of years

• For segments, the measure of exposure commonly used is millions of vehicle miles traveled

\[
VMT = 365 \times n \times \left( \frac{AADT}{10^6} \right) \times L
\]

- L: length of segment

(AASHTO 2009)
EPDO Average Crash Frequency (EPDO-CF)

- Data requirements:
  - Crash data by severity and location
  - Severity weighting factors
  - Crash costs by crash severity

- Formula:

\[
EPDO = \sum_{i} f_i N_i
\]
Weighting Factors $f_i$

• In HSM, factors are computed as follows:

$$f_i = \frac{CC_i}{CC_{PDO}}$$

$CC_i$ = cost for crash severity $i$

$CC_{PDO}$ = cost for PDO crash severity

• Care is needed to avoid possible biases
  • Cost associated with fatalities could override the analysis
“Fatal crashes are tragic events; however, the fact that they are fatal is often the outcome of factors (or a combination of factors) that is out of the control of the engineer and planner.”
Connecting Variables

• The total occurrence of crashes at a location is a function of multiple variables

• A way of connecting all those variables, mathematically, is through safety performance functions (SPFs)
SPFs

• An SPF can be an equation
  • used to predict the number of crashes per year at a location
  • function of exposure levels and/or location characteristics
  • Exposure: “measure of opportunities for accidents to occur” (Hauer 2015)

• Example: SPF for highway segments:
  \[ Predicted \text{Crashes} = \exp[\beta_0 + \beta_1 \ln(AADT) + \beta_2 \ln(Segment \text{Length})] \]

• SPF must not always be a mathematical equation
  • It can be an algorithm, a graph, or a table
Methods Described in the HSM (Performance Measures)

- Average crash frequency
- Crash rate
- EPDO average crash frequency
- Relative severity index
- Critical rate
- Excess predicted average crash frequency using method of moments
- Probability of specific crash types exceeding threshold proportion
- Excess proportion of specific crash types

- Level of service of safety
- Excess predicted average crash frequency using SPFs
- Expected average crash frequency with EB adjustment
- EPDO average crash frequency with EB adjustment
- Excess expected average crash frequency with EB adjustment

EPDO: equivalent property damage only
EB: empirical Bayes
SPF: safety performance function

(AASHTO 2009)
Safety Performance Functions in HSM

<table>
<thead>
<tr>
<th>HSM Chapter/ Facility Type</th>
<th>Undivided Roadway Segments</th>
<th>Divided Roadway Segments</th>
<th>Intersections</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Stop Control on Minor Leg(s)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3-Leg</td>
</tr>
<tr>
<td>10 - Rural Two-Lane Two-Way Roads</td>
<td>✓</td>
<td>-</td>
<td>✓</td>
</tr>
<tr>
<td>11 - Rural Multilane Highways</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>12 - Urban and Suburban Arterials</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

(Source: AASHTO 2009)
Safety Performance Functions for Prediction of Pedestrian Crashes

- Default distributions can be used to estimate the predicted pedestrian crashes based on the total crash safety performance functions.

<table>
<thead>
<tr>
<th>Collision type</th>
<th>Total fatal and injury</th>
<th>Property damage only</th>
<th>TOTAL (all severity levels combined)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SINGLE-VEHICLE ACCIDENTS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collision with animal</td>
<td>3.8</td>
<td>18.4</td>
<td>12.1</td>
</tr>
<tr>
<td>Collision with bicycle</td>
<td>0.4</td>
<td>0.1</td>
<td>0.2</td>
</tr>
<tr>
<td>Collision with pedestrian</td>
<td>0.7</td>
<td>0.1</td>
<td>0.3</td>
</tr>
<tr>
<td>Overturned</td>
<td>3.7</td>
<td>1.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Ran off road</td>
<td>54.5</td>
<td>50.5</td>
<td>52.1</td>
</tr>
<tr>
<td>Other single-vehicle accident</td>
<td>0.7</td>
<td>2.9</td>
<td>2.1</td>
</tr>
<tr>
<td>Total single-vehicle accidents</td>
<td>63.8</td>
<td>73.5</td>
<td>69.3</td>
</tr>
<tr>
<td><strong>MULTIPLE-VEHICLE ACCIDENTS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Angle collision</td>
<td>10.0</td>
<td>7.2</td>
<td>8.5</td>
</tr>
<tr>
<td>Head-on collision</td>
<td>3.4</td>
<td>0.3</td>
<td>1.6</td>
</tr>
<tr>
<td>Rear-end collision</td>
<td>16.4</td>
<td>12.2</td>
<td>14.2</td>
</tr>
<tr>
<td>Sideswipe collision B</td>
<td>3.8</td>
<td>3.8</td>
<td>3.7</td>
</tr>
<tr>
<td>Other multiple-vehicle collision</td>
<td>2.6</td>
<td>3.0</td>
<td>2.7</td>
</tr>
<tr>
<td>Total multiple-vehicle accidents</td>
<td>36.2</td>
<td>26.5</td>
<td>30.7</td>
</tr>
<tr>
<td>TOTAL ACCIDENTS</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>
Safety Performance Functions for Predicting Pedestrian Crashes at Signalized Intersections

\[ N_{\text{ped}} = N_{\text{pedbase}} \times \text{AMF}_{1p} \times \text{AMF}_{2p} \times \text{AMF}_{3p} \]  
\[ (12-28) \]

\[ N_{\text{pedbase}} = \exp (a + b \times \ln(AADT_{\text{tot}}) + c \times \ln \left( \frac{AADT_{\text{min}}}{AADT_{\text{maj}}} \right) + d \times \ln(\text{PedVol}) + e \times n_{\text{lanes}}) \]  
\[ (12-29) \]

(AASHTO 2009)
Safety Performance Functions for Predicting Pedestrian Crashes at STOP-Controlled Intersections

**SPFs for STOP-Controlled Intersections**

The number of vehicle-pedestrian collisions per year for a STOP-controlled intersection is estimated as:

\[ N_{\text{pedi}} = N_{\text{bi}} \times f_{\text{pedi}} \]  \hspace{1cm} (12-30)

Where,

\[ f_{\text{pedi}} = \text{pedestrian accident adjustment factor.} \]

**Exhibit 12-33: Pedestrian Accident Adjustment Factors for STOP-controlled Intersections**

<table>
<thead>
<tr>
<th>Intersection type</th>
<th>Pedestrian Accident Adjustment Factor ((f_{\text{pedi}}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>3ST</td>
<td>0.021</td>
</tr>
<tr>
<td>4ST</td>
<td>0.022</td>
</tr>
</tbody>
</table>

Note: These factors apply to the methodology for predicting total crashes (all severity levels combined). All pedestrian collisions resulting from this adjustment factor are treated as fatal-and-injury crashes and none as property-damage-only crashes. Source: HSIS data for California (2002-2006)
### Safety Performance Functions for Prediction of Pedestrian Crashes

<table>
<thead>
<tr>
<th>Chapter 12 SPFs for Urban and Suburban Arterials</th>
<th>SPF Components by Collision type</th>
<th>SPF Equations and Exhibits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roadway segments</td>
<td>multiple-vehicle nondriveway collisions</td>
<td>Equations 12-10, 12-11, 12-12, Exhibits 12-5, 12-6, 12-7</td>
</tr>
<tr>
<td></td>
<td>single-vehicle crashes</td>
<td>Equations 12-13, 12-14, 12-15, Exhibits 12-8, 12-9, 12-10</td>
</tr>
<tr>
<td></td>
<td>multiple-vehicle driveway-related collisions</td>
<td>Equations 12-16, 12-17, 12-18, Exhibits 12-11, 12-12, 12-13, 12-14, 12-15, 12-16</td>
</tr>
<tr>
<td></td>
<td>vehicle-pedestrian collisions</td>
<td>Equation 12-19 Exhibit 12-17</td>
</tr>
<tr>
<td></td>
<td>vehicle-bicycle collisions</td>
<td>Equation 12-20, Exhibit 12-18</td>
</tr>
<tr>
<td>Intersections</td>
<td>multiple-vehicle collisions</td>
<td>Equations 12-21, 12-22, 12-23, Exhibit 12-19, 12-20, 12-21, 12-22, 12-23, 12-24</td>
</tr>
<tr>
<td></td>
<td>single-vehicle crashes</td>
<td>Equations 12-24, 12-25, 12-26, 12-27, Exhibit 12-25, 12-26, 12-27, 12-28, 12-29, 12-30</td>
</tr>
<tr>
<td></td>
<td>vehicle-pedestrian collisions</td>
<td>Equations 12-28, 12-29, 12-30, Exhibits 12-31, 12-32, 12-33</td>
</tr>
<tr>
<td></td>
<td>vehicle-bicycle collisions</td>
<td>Equation 12-31, Exhibit 12-34</td>
</tr>
</tbody>
</table>
Other Crash Data-Based Methods for Pedestrian Crash Hotspot Identification

- Density methods
- Clustering methods
- Exposure estimation methods
Density Method (Pulugurtha et al. 2007)

• A GIS-based method

• Procedure:
  • Step 1. Geocode pedestrian crash data
  • Step 2. Create a crash concentration map
  • Step 3. Identify zones, their shapes and sizes

Fig. 2. Circular search area around each cell—Simple Method.
Fig. 6. Spatial distributions of pedestrian crashes in the Las Vegas (1998–2002).

(Source: Pulugurtha et al. 2007)
Fig. 7. High pedestrian crash zones in the Las Vegas metropolitan area.

(Source: Pulugurtha et al. 2007)
Surrogate Measures: Pedestrian and Bicycle Intersection Safety Indices (Ped ISI and Bike ISI)

• The indices are intended for identification of intersection crossings and intersection approach legs that should be prioritized for the implementation safety improvements
Where Ped ISI can be Used

• Ped ISI were developed for urban and suburban intersections with the following characteristics:
  • Three-leg and four-leg intersections.
  • Signalized, two-way stop, and four-way stop.
  • Traffic volumes from 600 to 50,000 vehicles per day.
  • One-way and two-way roads.
  • One to four through lanes.
  • Speed limits from 24.1 to 72.4 km/h (15 to 45 mph).

(Carter et al. 2007)
Data and Methodology Used in the Development of Ped ISI

• Data:
  • 68 signalized and unsignalized pedestrians crossings
  • Crossings from Miami, FL (23 sites); Philadelphia, PA (22 sites); and San Jose, CA (23 sites)

• Two measures used to compute Ped ISI
  • Safety rating for each site based on experts opinions
    • Multiple linear regression models estimated using the ratings
  • Observed behaviors between pedestrians and motorists
    • Generalized linear models estimated using observed
Data Required to Compute Ped ISI

- Type of traffic control for leg of crossing (signal, stop sign, or neither)
- Number of through vehicle lanes on main street (total through lanes in both directions)
- 85th percentile traffic speed on main street
- Average daily traffic (ADT) of main street
- Predominant development type surrounding the intersection (commercial or not commercial)

(Carter et al. 2007)
Steps for Using Ped ISI

1. Select sites to evaluate
   - Sites where crashes have occurred
   - Sites where the community has expressed concern
   - Sites with high volume of pedestrians

2. Gather data

3. Calculate index values

4. Prioritize sites
Ped ISI

\[
\text{Ped ISI} = 2.372 - 1.867 \text{SIGNAL} - 1.807 \text{STOP} + 0.335 \text{THRULNS} + 0.018 \text{SPEED} + 0.006 (\text{MAINADT} \times \text{SIGNAL}) + 0.238 \text{COMM}
\]

where:

<table>
<thead>
<tr>
<th>Ped ISI</th>
<th>Safety index value (pedestrian)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIGNAL</td>
<td>Signal-controlled crossing</td>
</tr>
<tr>
<td>STOP</td>
<td>Stop-sign controlled crossing</td>
</tr>
<tr>
<td>THRULNS</td>
<td>Number of through lanes on street being crossed (both directions)</td>
</tr>
<tr>
<td>SPEED</td>
<td>Eighty-fifth percentile speed of street being crossed</td>
</tr>
<tr>
<td>MAINADT</td>
<td>Main street traffic volume (ADT in thousands)</td>
</tr>
<tr>
<td>COMM</td>
<td>Predominant land use on surrounding area is commercial development (i.e., retail, restaurants)</td>
</tr>
</tbody>
</table>

(Carter et al. 2007)
Maybe the absence of pedestrian related crashes is evidence of a pedestrian safety problem.

Do you agree with this idea?

In what scenario could it be true?
Understanding the Nature of Pedestrian Safety Problems
Diagnosing the Pedestrian Safety Problems

• Two perspectives
  • Analysis that follows the network screening step (as part of the road safety management process)
  • Analysis as part of a continuous effort to monitor the general safety of the road network
Road Safety Management Process

- Network Screening
- Diagnosis
- Project Selection
- Evaluation
- Appraisal
- Countermeasures
Diagnosis

• “Diagnosis is designed to identify a dominant or abnormally high proportion of particular collision configurations (e.g., rear end, right angle, etc.) at a target location” (Park and Sahaji 2013)

• Outcome of a diagnosis:
  • Identification of the causes of the collisions and potential safety concerns or crash patterns that can be evaluated further

• Steps:
  1. Safety data review
  2. Assess supporting documentation
  3. Assess field condition
Diagnosis Methodology

• Two methodologies mentioned in the HSM:
  
  • Descriptive data analysis methodology
    • Appears in Chapter 5 of the HSM, the Diagnosis chapter
  
  • Beta binomial test

• Other methodologies can be found in the literature
Step 1 – Safety Data Review

• Aim of the data review is to identify patterns in:
  • Crash type
  • Crash severity
  • Environmental conditions
  • Driver behavior
  • Time of day
  • Direction of travel prior to crash
Step 2 – Assess Supporting Documents

• What constitutes supporting documentation?
  • As-built construction plans
    • Geometric changes may explain changes in crash patterns
  • Past studies
  • Past traffic counts
  • Current traffic volumes for all modes
  • Relevant design criteria and pertinent guidelines
  • Inventory of field conditions (e.g., traffic signs, traffic control devices, number of travel lanes, posted speed limits, etc.)
  • Maintenance logs
  • Land use mapping and traffic access control characteristics
  • Historic patterns of adverse weather
Step 3 – Assess Field Conditions

• Site visits validate concerns found during the review of crash data and/or supporting documentation
  • Obviously, it may reveal concerns not found in documents

• Comprehensive field assessment involves travel through the site from all possible directions and modes
  • Determine what is the typical experience of the traveler
  • Consider all modes
  • Visit at different times of the day and different weather conditions

• What should be assessed in a field visit?
What is the Difference between the Diagnosis Assessment-of-Conditions step and a Road Safety Audit (RSA)?

• Who performs the assessment?

• Why are facilities visited?

• General objectives are similar
Pedestrian Road Safety Audit Guidelines and Prompt Lists

FHWA-SA-07-007
June 2007

Making Your Roads Safer

Federal Highway Administration
What are Road Safety Audits (RSAs)?

“A formal safety examination of a future roadway plan or project or an in-service facility that is conducted by an independent, experienced multidisciplinary RSA team”

• RSAs generally involve an examination of pedestrian safety

• However, special focus RSAs can be perform to identify and improve pedestrian safety problems

(Nabors et al. 2007)
RSAs

• The objective of RSAs is to assess if the operations of roadways and highways provide a safe environment for all road users
  • Not a review of design standards or policies
  • A review of site elements

• RSAs should be conducted on all project planning stages

• Many old facilities do not meet safety standards for pedestrians

(Nabors et al. 2007)
Knowledge Base as part of Pedestrian Focused RSA

• Members of RSA team should be familiar with:
  • AASHTO A Policy on Geometric Design of Highways and Streets (Green Book)
  • American Disabilities Act (ADA)
  • Manual on Uniform Traffic Control Devices (MUTCD)
  • State/local documents, including relevant laws and statutes concerning pedestrians and motorists

(Nabors et al. 2007)
Knowledge Base as part of Pedestrian Focused RSA

• Members of RSA team should be familiar with:
  • *FHWA Designing Sidewalks and Trails for Access, Part I, A Review of Existing Guidelines*
  
  • *FHWA Designing Sidewalks and Trails for Access Part II, Best Practices Guide*
  
  • *FHWA Accessible Sidewalks and Street Crossings - An Informational Guide*
  
  • *AASHTO Guide for the Planning, Design, and Operation of Pedestrian Facilities*
When RSAs should be Conducted

• Pre-construction stage
  • Planning
  • Preliminary design
  • Final design

• Construction stage

• Post-construction state
  • RSA on existing roads/facilities in operation

(Nabors et al. 2007)
<table>
<thead>
<tr>
<th>Typical 8 RSA Steps</th>
<th>Responsibilities</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong> Identify project or existing road for RSA</td>
<td>![Project Owner/Design Team] ![RSA Team]</td>
</tr>
<tr>
<td><strong>Step 2</strong> Select multi-disciplinary RSA team</td>
<td>![Project Owner/Design Team] ![RSA Team]</td>
</tr>
<tr>
<td><strong>Step 3</strong> Conduct start-up meeting to exchange information</td>
<td>![Project Owner/Design Team] ![RSA Team]</td>
</tr>
<tr>
<td><strong>Step 4</strong> Perform field reviews under various conditions</td>
<td>![Project Owner/Design Team] ![RSA Team]</td>
</tr>
<tr>
<td><strong>Step 5</strong> Conduct RSA analysis and prepare report of findings</td>
<td>![Project Owner/Design Team] ![RSA Team]</td>
</tr>
<tr>
<td><strong>Step 6</strong> Present RSA findings to Project Owner / Design Team</td>
<td>![Project Owner/Design Team] ![RSA Team]</td>
</tr>
<tr>
<td><strong>Step 7</strong> Prepare formal response</td>
<td>![Project Owner/Design Team] ![RSA Team]</td>
</tr>
<tr>
<td><strong>Step 8</strong> Incorporate findings into project when appropriate</td>
<td>![Project Owner/Design Team] ![RSA Team]</td>
</tr>
</tbody>
</table>

*The responsibilities of the project owner/design team and the RSA team vary during the course of an RSA.*

(Source: Nabors et al. 2007)
Performing Field Reviews Under Various Conditions

• As a minimum, field reviews should include:
  • Walk-through
    • Daytime and nighttime
      • Are pedestrians visible at night?
      • At the points when pedestrians enter, what would be the tasks being performed by drivers?
    • Observations of pedestrian behavior, not only design elements
    • All modes considered, not only pedestrians (helpful for identifying risk factors)
    • Peak and off-peak traffic conditions
    • Different weather conditions

(Nabors et al. 2007)
Performing Field Reviews Under Various Conditions

• As a minimum, field reviews should include:
  • Consideration of different pedestrian abilities
    • How do children interact with the facility?
    • How comfortable is it for the elderly?

• Treatment and transition of pedestrian facilities at the project limits
  • To what degree is the facility connected to the sidewalk system?
  • Are pedestrians forced to engage in risky behavior due to lack of system connectivity?

(Nabors et al. 2007)
RSA Analysis and Report

- RSA report may include a crash risk assessment
  - Analysis of expected crash rate frequency
  - Analysis of expected crash severity

- Qualitative assessment of crash rate frequency can be performed on the basis of expected exposure and probability
  - “How many road users will likely be exposed to the identified safety issue?” (expected exposure)
  - “How likely is it that a collision will result from the identified issue?” (probability)
RSA Analysis and Report

• Factors that affect the expected crash severity
  • Anticipated speeds
  • Expected collision types
  • Expected presence of vulnerable users (e.g., elderly pedestrians)

Qualitative Crash Risk

<table>
<thead>
<tr>
<th>FREQUENCY RATING</th>
<th>SEVERITY RATING</th>
</tr>
</thead>
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<tr>
<td></td>
<td>Minor</td>
</tr>
<tr>
<td>Frequent</td>
<td>Moderate-High</td>
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<tr>
<td>Occasional</td>
<td>Moderate</td>
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<tr>
<td>Infrequent</td>
<td>Low</td>
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<tr>
<td>Rare</td>
<td>Lowest</td>
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</tbody>
</table>

(Nabors et al. 2007)
Speed and Crash Severity

(Source: Rosen et al. 2011)
Speed and Crash Severity

$P(\text{death}) = \frac{1}{1 + \exp(6.9 - 0.090V)}$

$P(\text{death}) = \frac{1}{1 + \exp(9.1 - 0.95V - 0.040AGE)}$

where:

$P(\text{death})$ : Probability of death

$V$ : Impact velocity (km/h)

$AGE$ : Pedestrian age (years) (greater than 15)

(Rosen and Sander 2009)
Pedestrian-Oriented RSA Master Prompt List

• Master prompt list consists of two basic elements:
  • Universal considerations
  • Matrix of pedestrians prompts

• RSA Matrix
  • 3 major topics
    • Pedestrian facilities
    • Traffic
    • Traffic Control Devices
  • 9 subtopics

(Nabors et al. 2007)
Universal Considerations
(For Entire RSA Site)

I. Needs of Pedestrians: Do pedestrian facilities address the needs of all pedestrians?

II. Connectivity and Convenience of Pedestrian Facilities: Are safe, continuous, and convenient paths provided along pedestrian routes throughout the study area?

III. Traffic: Are design, posted, and operating traffic speeds compatible with pedestrian safety?

IV. Behavior: Do pedestrians or motorists regularly misuse or ignore pedestrian facilities?

V. Construction: Have the effects of construction on all pedestrians been addressed adequately?

VI. School Presence: Is the safety of children in school zones adequately considered?
<table>
<thead>
<tr>
<th>Topic</th>
<th>Subtopic</th>
<th>RSA Zones</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>B. Street Crossings: Crossing treatments, intersections</td>
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<td></td>
<td></td>
<td>C. Parking Areas/Adjacent Developments: Sidewalks and paths</td>
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<td></td>
<td></td>
<td>D. Transit Areas: Seating, shelter, waiting/loading/unloading areas</td>
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<td></td>
<td>2. Quality, Condition, and Obstructions</td>
<td>A. Streets: Sidewalks, paths, ramps, and buffers</td>
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<td></td>
<td></td>
<td>B. Street Crossings: Crossing treatments (see prompts in A)</td>
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<td>C. Parking Areas/Adjacent Developments: Sidewalks and paths</td>
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<td>D. Transit Areas: Seating, shelter, waiting/loading/unloading areas (see prompts in A)</td>
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<td>3. Continuity and Connectivity</td>
<td>A. Streets: Continuity/connectivity with other streets and crossings</td>
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<td>B. Street Crossings: Continuity/connectivity of crossing to ped network;</td>
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<td>channelization of peds to appropriate crossing points</td>
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<td>C. Parking Areas/Adjacent Developments: Continuity/connectivity of pedestrian facilities through parking lots/adjacent developments</td>
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<td>D. Transit Areas: Connectivity of ped network to transit stops</td>
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<td>4. Lighting</td>
<td>A. Streets: Pedestrian lighting along the street</td>
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<td>B. Street Crossings: Lighting of crossing</td>
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<td>C. Parking Areas/Adjacent Developments: Pedestrian level lighting in parking lots/adjacent developments (see prompts in A and B)</td>
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<td>D. Transit Areas: Lighting at and near transit stop</td>
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<td>5. Visibility</td>
<td>A. Streets: Visibility of all road users</td>
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<td>B. Street Crossings: Visibility of crossing/waiting pedestrians and oncoming traffic</td>
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<td></td>
<td>C. Parking Areas/Adjacent Developments: Visibility of pedestrians and backing/tuning vehicles; visibility of pedestrian path</td>
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<td>D. Transit Areas: Visibility of pedestrians/waiting passengers and vehicles/buses</td>
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<td>Topic</td>
<td>Subtopic</td>
<td>RSA Zones</td>
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<td>A. Streets</td>
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<td>Traffic</td>
<td>6. Access Management</td>
<td>Driveway placement and design along streets</td>
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<td>B. Street Crossings</td>
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<td>C. Parking Areas/Adjacent Developments</td>
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<td>D. Transit Areas</td>
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<td></td>
<td>7. Traffic</td>
<td>Volume and speed of adjacent traffic, conflicting conditions</td>
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<td>Volume and speed of traffic approaching crossing, conflicting movements</td>
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<td>Traffic volume and speed in parking lots and developments, conflicting conditions</td>
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<tr>
<td></td>
<td></td>
<td>Volume and speed of adjacent traffic and traffic at crossings to bus stops, conflicting conditions</td>
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<tr>
<td>Topic</td>
<td>Subtopic</td>
<td>RSA Zones</td>
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<tr>
<td>Traffic Control Devices</td>
<td>8. Signs and Pavement Markings</td>
<td>A. Streets: Use and condition of signs, pavement markings, and route indicators</td>
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<td></td>
<td></td>
<td>B. Street Crossings: Use and condition of signs, pavement markings, and crossing indicators</td>
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<td></td>
<td></td>
<td>C. Parking Areas/Adjacent Developments: Use and condition of signs, pavement markings for travel path and crossing</td>
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<td>D. Transit Areas: Use and condition of transit-related signs and pavement markings</td>
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<tr>
<td></td>
<td>9. Signals</td>
<td>A. Streets: Use and condition of signs, pavement markings, and route indicators</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B. Street Crossings: Presence, condition, timing, and phasing of signals</td>
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<td></td>
<td></td>
<td>C. Parking Areas/Adjacent Developments: n/a*</td>
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<td></td>
<td></td>
<td>D. Transit Areas: See prompts in B</td>
</tr>
</tbody>
</table>

(Nabors et al. 2007)
Example of Detailed Prompt List

- As their name suggests, detailed prompt list go into more details on the type of considerations that should be accounted for in a site visit.

- “The prompt lists are **not checklists** that provide a simple listing of all pedestrian items to be considered in an RSA.”

<table>
<thead>
<tr>
<th>Master Prompt</th>
<th>Detailed Prompt</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>B.1 Presence, Design, and Placement</strong></td>
<td></td>
</tr>
<tr>
<td>B.1.1</td>
<td>Do wide curb radii lengthen pedestrian crossing distances and encourage high-speed right turns?</td>
</tr>
<tr>
<td>B.1.2</td>
<td>Do channelized right turn lanes minimize conflicts with pedestrians?</td>
</tr>
<tr>
<td>B.1.3</td>
<td>Does a skewed intersection direct drivers focus away from crossing pedestrians?</td>
</tr>
<tr>
<td>B.1.4</td>
<td>Are pedestrian crossings located in areas where sight distance may be a problem?</td>
</tr>
<tr>
<td>B.1.5</td>
<td>Do raised medians provide a safe waiting area (refuge) for pedestrians?</td>
</tr>
<tr>
<td>B.1.6</td>
<td>Are supervised crossings adequately staffed by qualified crossing guards?</td>
</tr>
<tr>
<td>B.1.7</td>
<td>Are marked crosswalks wide enough?</td>
</tr>
<tr>
<td>B.1.8</td>
<td>Do at-grade railroad crossings accommodate pedestrians safely?</td>
</tr>
<tr>
<td>B.1.9</td>
<td>Are crosswalks sited along pedestrian desire lines?</td>
</tr>
<tr>
<td>B.1.10</td>
<td>Are corners and curb ramps appropriately planned and designed at each approach to the crossing?</td>
</tr>
</tbody>
</table>

See prompts in Section A for potential issues on obstructions and prc.
Universal Considerations: Needs of Pedestrians

• Do pedestrian facilities address the needs of all pedestrians?
  • Seniors
  • Children
  • People in wheelchairs, scooters, with strollers, or dollies
  • People with visual impairments (e.g., color blindness)
Universal Considerations:
Connectivity and Convenience of Pedestrian Facilities

• Connectivity
  • Are there gaps in the pedestrian networks?
  • Is the existing pedestrian network continuous?

• Convenience
  • How directly does the pedestrian network follow desired lines?

• Connectivity and Convenience often deficient in:
  • Large arterial roads
  • Interchanges in urban areas
  • Private development

(Nabors et al. 2007)
Universal Considerations: Behavior of Pedestrians and Motorists

• Do pedestrians regularly misuse or ignore the pedestrian facilities?
  • If so, is this behavior due to the fact that the facilities are
    • dangerous,
    • inconvenient, or
    • inappropriately placed?

• Do motorists regularly ignore the pedestrian facilities?
  • Do motorists yield for pedestrians at crossings?
  • Do motorists observe traffic control devices?
Universal Considerations: Construction

• Have the effects of construction on all pedestrians been addressed adequately?
  • Has pedestrian network connectivity being affected by the construction?
    • If so, have appropriate steps been taken to maintain clear pedestrian paths?
    • Or, has the construction forced pedestrians into dangerous situations?
    • Have alternate pedestrian paths been provided?
  • Are the alternative detour paths accessible and safe for all pedestrians?
  • Has proper guidance been provided to route pedestrians to the alternative paths?
Universal Considerations: School Presence

• Are areas adjacent to the school safe for child pedestrians?
  • Is the signage in at the school zone adequate and effective?
  • Is the school connected to a pedestrian network that also connects to residential areas?
  • Are crossings in school zones marked as school crossings?
Example of Pedestrian Facilities Adjacent to UPRM
Summary

- There are multiple methods for identifying locations that represent a significant danger for pedestrians
  - Crash data based methods
  - Surrogate-based method

- Determining the nature of pedestrian safety problems requires:
  - Review of supporting data and documents
  - Site visits under different operational conditions
References

References


PART C.
PEDESTRIAN SAFETY COUNTERMEASURES AND COUNTERMEASURE SELECTION
Overview of Part C

• Introduction to countermeasure selection process

• Discussion of specific pedestrian safety countermeasures

• Overview of PEDSAFE Countermeasure Selection Tool

• Review of countermeasure selection methods
Road Safety Management Process

- Network Screening
- Diagnosis
- Counter-measures
- Evaluation
- Project Selection
- Appraisal
Countermeasure Selection Process
Countermeasures

• Purpose is to decrease crash frequency, severity, or both

• Obviously, countermeasure selection depends on an analysis of contributing factors for the observed problems
Steps for Countermeasure Selection

1. Identify factors contributing to crashes at the subject site

2. Identify countermeasures which may address the contributing factors

3. Select preferred treatment(s)
1. Identifying Contributing Factors

- Three basic categories
  - Human factors
  - Vehicle factors
  - Roadway/environmental factors

<table>
<thead>
<tr>
<th>Period</th>
<th>Human Factors</th>
<th>Vehicle Factors</th>
<th>Roadway Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before the Crash</td>
<td>distraction, fatigue, inattention, bad judgment,</td>
<td>bald tires, worn brakes</td>
<td>wet pavement, polished aggregate, steep downgrade, poor signal coordination,</td>
</tr>
<tr>
<td>(Causes of the hazardous</td>
<td>age, cell phone use, impaired cognitive skills,</td>
<td></td>
<td>limited stopping sight distance, lack of warning signs</td>
</tr>
<tr>
<td>situation)</td>
<td>deficient driving habits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>During the Crash</td>
<td>vulnerability to injury, age, failure to wear a</td>
<td>bumper heights and energy absorption, headrest</td>
<td>pavement friction and grade</td>
</tr>
<tr>
<td>(Causes of crash severity)</td>
<td>seat belt</td>
<td>design, airbag operations</td>
<td></td>
</tr>
<tr>
<td>After the Crash</td>
<td>age, gender</td>
<td>ease of removal of injured passengers</td>
<td>the time and quality of the emergency response, subsequent medical treatment</td>
</tr>
<tr>
<td>(Factors of crash outcome)</td>
<td></td>
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</tr>
</tbody>
</table>

(AASHTO 2009)
2. Identify Countermeasures

• Requires engineering judgment and local knowledge
  • For example, roundabouts introduced where they have never existed before?

• Crash Modification Factors (CMFs) provide an idea of possible countermeasure effects

• A countermeasure may address a problem, but create other problems
  • “For example, installing a traffic signal in a rural environment at a previously unsignalized two-way stop-controlled intersection has CMF of 1.58 for rear-end crashes and an CMF of 0.40 for left-turn crashes”
CMFs in the HSM

• CMFs are the focus of Part D of the HSM

<table>
<thead>
<tr>
<th>Chapter</th>
<th>CMF Subject</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>Roadway Segments</td>
</tr>
<tr>
<td>14</td>
<td>Intersections</td>
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<tr>
<td>15</td>
<td>Interchanges</td>
</tr>
<tr>
<td>16</td>
<td>Special Facilities and Geometric Situations</td>
</tr>
<tr>
<td>17</td>
<td>Road Networks</td>
</tr>
</tbody>
</table>
CMFs in the Clearinghouse

Real world safety: The benefits of using CMFs to predict and prioritize

Join us for a webinar on Dec. 8! Click here for more details.
3. Select Preferred Treatments(s)

• If possible, conduct cost-benefit analysis
  • Attempt to quantify crash reductions
  • Determine implementation costs

• Optimization procedures might be useful
  • Depends on the number of possible viable projects
Pedestrian Safety Countermeasures
Pedestrian Safety Countermeasures

• The FHWA has created a valuable tool for the identification of pedestrian safety countermeasures: PEDSAFE

• The information presented in the next slides was extracted from PEDSAFE (Zeeger et al. 2013)
The Pedestrian Safety Guide and Countermeasure Selection System is intended to provide practitioners with the latest information available for improving the safety and mobility of those who walk. The online tools provide the user with a list of possible engineering, education, or enforcement treatments to improve pedestrian safety and/or mobility based on user input about a specific location.

**GUIDE**

**Background**
Understand what is needed to create a viable pedestrian system.

**Analysis**
How crash typing can lead to the most appropriate countermeasures.

**Statistics**
Learn about the factors related to the pedestrian crash problem.

**Implementation**
Needed components for treatments.
Types of Pedestrian Crashes

1. Dart/Dash
2. Multiple Threat/Trapped
3. Unique Midblock (Mailbox, Ice Cream Vendor, Parked Vehicle)
4. Through Vehicle at Unsignalized Location
5. Bus-Related
6. Turning Vehicle
7. Through Vehicle at Signalized Location
8. Walking Along Roadway
9. Working/Playing in Road
10. Non-Roadway (Sidewalk, Driveway, Parking Lot, or Other)
11. Backing Vehicle
12. Crossing Expressway
13. Miscellaneous
Categorizations for Pedestrian Related Countermeasures

- Along the roadway
- Crossing locations
- Transit
- Roadway Design
- Traffic Calming
- Traffic Management
- Signals and Signs
- Other Measures

PEDSAFE presents 67 engineering, education, and enforcement countermeasures
<table>
<thead>
<tr>
<th>Crash Type</th>
<th>Along Roadway</th>
<th>Crossing Locations</th>
<th>Transit</th>
<th>Roadway Design</th>
<th>Intersection Design</th>
<th>Traffic Calming</th>
<th>Traffic Mgmt.</th>
<th>Signals/Signs</th>
<th>Other</th>
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<td>Dart/Dash</td>
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<td>Multiple Threat/Trapped</td>
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<td>Unique Midblock</td>
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<td>Through Vehicle at Unsignalized Location</td>
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<td>Turning Vehicle</td>
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<td>Objective Type</td>
<td>Along Roadway</td>
<td>Crossing Locations</td>
<td>Transit</td>
<td>Roadway Design</td>
<td>Intersection Design</td>
<td>Traffic Calming</td>
<td>Traffic Mgmt.</td>
<td>Signals/Signs</td>
<td>Other</td>
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<td>Reduce Speed of Motor Vehicles</td>
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<td>Improve Sight Distance and Visibility for Motor Vehicles and Pedestrians</td>
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<td>Reduce Volume of Motor Vehicles</td>
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<td>Reduce Exposure for Pedestrians</td>
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<td>Improve Pedestrian Access and Mobility</td>
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<tr>
<td>Encourage Walking by Improving Aesthetics</td>
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<td>Improve Compliance With Traffic Laws</td>
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<tr>
<td>Eliminate Behaviors That Lead to Crashes</td>
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</table>
Along the Roadway Countermeasures

• Sidewalks, Walkways, and Paved Shoulders

• Street Furniture/Walking Environment
Along the Roadway Countermeasures: Sidewalks, Walkways and Paved Shoulders

• The pedestrians lanes

• Minimum recommended width: 5ft
  • Wider sidewalks at locations with high concentration of pedestrians (e.g., transit stops, schools)

• “A buffer zone of 4 to 6 feet is desirable to separate pedestrians from the street.”

(Source: PEDSAFE)
Along the Roadway Countermeasures: Street Furniture/Walking Environment

• Influences how safe pedestrians feel
  • Consider concept of allowances

• Goal is to create a safe, functional, and pleasant experience for pedestrians

• Ensure that street furniture does not obstruct walkways
Countermeasures at Crossing Locations

• Curb Ramps
• Marked Crosswalks and Enhancements
• Curb Extensions
• Crossing Islands
• Raised Pedestrian Crossings
• Lighting and Illumination
• Parking Restrictions (at Crossing Locations)
• Pedestrian Overpasses/Underpasses
• Automated Pedestrian Detection
• Leading Pedestrian Interval
• Advance Yield/Stop Lines
Countermeasures at Crossing Locations: Curb Extensions

(Source: Wikipedia)
Curb Extensions in Mayagüez
Countermeasures at Crossing Locations: Curb Ramps

• “Curb ramps must be installed at all intersections and midblock locations where there are pedestrian crossings, as mandated by federal legislation”
  • Requirement of the Americans with Disabilities Act

• Provides access to sidewalk

• Slope:
  • Not more than 1:12 (1 in/ft)
  • Maximum slope on side flares must not exceed 1:10
Countermeasures at Crossing Locations: Crossing Islands

• Raised roadway elements located “in the center of the street at intersections or midblock crossings”

• Recommended width of 4 ft. (preferably 8 ft.)

• Reduce pedestrian-related crashes by 46 percent at marked crossings, and by 39 percent at unmarked crossings

(PEDSAFE)
Countermeasures at Crossing Locations: Raised Pedestrian Crossings

- Usually located at a midblock crossing
  - Typical width: 10-15ft

- Vehicle speeds are reduced

- Eliminates the need to construct curb ramps
Countermeasures at Crossing Locations: Lighting and Illumination

- Luminaire should not be placed directly over crosswalks
  - Offset of 10 ft. from crosswalk

- “[L]uminaires should also be placed before the crosswalk on the approach into the intersection”

- Uniform lighting levels
Countermeasures at Crossing Locations: Automated Pedestrian Detection

• Use infrared detector or pressure sensitive mat

• Helps visually impaired people

• “[S]tudies have shown that many pedestrians ignore the button or believe that the button is malfunctioning if there is a significant delay in receiving a signal”
Transit-Related Countermeasures

• Transit Stop Improvements

• Access to Transit

• Bus Bulb Outs
Transit-Related Countermeasure: Transit Stop Improvements

• Clear and visible paths to stops

• Transit stop furniture should not obstruct pedestrian traffic

• Sufficient space should be allocated to the stop so that passenger accumulation does not create pathway obstructions
Transit-Related Countermeasure: Access to Transit

• Stop locations is a critical issue
  • Should take into account transit user behaviors (e.g., effort to catch a bus transfer)

• Stops should generally be located at intersections (far-side placement)
  • Easier for people to cross quickly to catch connecting bus

(Source: PEDSAFE)
Transit-Related Countermeasure: Bus Bulb Outs

(Source: PEDSAFE)
Roadway Design Countermeasures

- Bicycle Lanes
- Lane Narrowing
- Lane Reduction (Road Diet)
- Driveway Improvements
- Raised Medians
- One-way/Two-way Street Conversions
- Improved Right-Turn Slip-Lane Design
Roadway Design Countermeasure: Lane Narrowing

• Recommended minimums (AASHTO’s Green Book):
  • 9 ft. lanes on rural roadways
  • 10 ft. for most vehicular travel lanes
  • 10 ft. for turn lanes
  • 11 ft. for lanes to accommodate large volumes of trucks

• Purpose:
  • Reduces speeds
  • Provides space for expanding sidewalks or creating bike lanes
Roadway Design Countermeasure: Road Diet

(Source: bicycletucson.com)
Roadway Design Countermeasure: Driveway Improvements

• “Driveways built like intersections encourage high-speed turns”
  • Reduced turn radii
  • Narrow lanes

• When driveways cross sidewalks, continuity should be preserved
  • Special attention to wheelchair user needs
Roadway Design Countermeasure: Raised Medians

• Possible benefits
  • Reduce passenger crossing distance
  • Increase pedestrian visibility
  • Allow pedestrians to focus on one direction of traffic at a time when crossing

• Unintended consequences
  • May reduced “perceived friction”; increase speeds
  • Space could be allocated to better use

Example of a well-designed right-turn slip lane with a refuge islands that forces pedestrians to face on-coming traffic, and marked crosswalks. Source: Living Streets (Dan Burden)

Raised landscaped median. Source: Designing for Pedestrian Safety
Roadway Design Countermeasure: One-way/Two-way Street Conversions

• Context-specific conversions

• Benefits of one-way streets
  • Pedestrian has to focus on only one direction of traffic
  • Fewer turning movements

• Benefits of two-way streets
  • Lower speeds
Intersection Design Countermeasures

• Roundabouts
• Modified T-Intersections
• Intersection Median Barriers
• Curb Radius Reduction
• Modify Skewed Intersections
• Pedestrian Accommodations at Complex Interchanges
Intersection Design Countermeasures: Roundabouts

(Source: PEDSAFE)
Intersection Design Countermeasures: Modified T Intersections

(Source: PEDSAFE)
Intersection Design Countermeasures: Intersection Median Barriers

• Barriers located in the middle of an intersection

• Eliminates left-turn and cross-street movement

• Barriers reduce vehicle-pedestrian conflicts and provide refuge for pedestrians
Intersection Design Countermeasures: Modify Skewed Intersections

• Skewed intersections generally result in higher speeds and longer pedestrian crossing distances
  • Realignment could fix these problems

• Intersections “should be designed so that the angle between intersecting streets is as close to 90 degrees as possible”
Traffic Calming Countermeasures

• Temporary Installations for Traffic Calming
• Chokers
• Chicanes
• Mini-Circles
• Speed Humps
• Speed Tables
• Gateways
• Landscaping
• Specific Paving Treatments
• Serpentine Design
Traffic Calming Countermeasures: Chicanes and Serpentine Design

(Source: CMAP Illinois)
Traffic Calming Countermeasures: Chokers

• “[D]esigned to slow vehicles at a mid-point along the street through narrowing the street width at a specific location”

• When a two-lane street is reduced to a single lane, a 16 ft. width is recommended

A choker that requires motorists to yield to each other in Charlotte, North Carolina. Source: City of Charlotte
Traffic Calming Countermeasures: Mini-Circles

- Implemented at residential street intersections

- “Mini-circles have been found to reduce motor vehicle crashes by an average of 90 percent in Seattle, WA”

- Use yields signs, not stop signs

- Consider “creating a mountable curb in the outer portion of the circle”
Traffic Calming Countermeasures: Speed Humps and Tables

• Not speed bumps

• 12 ft. hump = 15-20 mph design speed
• 22 ft. hump = 25-30 mph design speed

• “Devise of last resort” that should only be used on local streets

• Speed tables are speed humps with a broad flat top

(PEDSAFE)
Speed Humps at UPRM
Traffic Calming Countermeasures: Landscaping

Landscaping can be used to calm traffic by visually narrowing the roadway. Source: pedbikeimages.org - Carl Sundstrom (2008)

Landscaping can provide a physical barrier between pedestrians and motorists. Source: Gina Coffman (2012)
Traffic Management Countermeasures

• Diverters
• Full Street Closure
• Partial Street Closure
• Left Turn Prohibitions
Traffic Management Countermeasures: Diverters

(Source: nacto.org)
Signal and Signs Countermeasures

- Traffic Signals
- Pedestrian Signals
- Pedestrian Signal Timing
- Traffic Signal Enhancements
- Right-Turn-on-Red Restrictions
- Advanced Stop Lines at Traffic Signals
- Left Turn Phasing
- Push Buttons & Signal Timing
- Pedestrian Hybrid Beacon (PHB)
- Rectangular Rapid Flash Beacon (RRFB)
- Puffin Crossing
- Signing
Signals and Signs Countermeasures: Pedestrian Signals

<table>
<thead>
<tr>
<th>Infrastructure</th>
<th>Description</th>
<th>Median</th>
<th>Average</th>
<th>Min. Low</th>
<th>Max. High</th>
<th>Cost Unit</th>
<th># of Sources (Observations)</th>
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</thead>
<tbody>
<tr>
<td>Signal</td>
<td>Audible Pedestrian Signal</td>
<td>$810</td>
<td>$800</td>
<td>$550</td>
<td>$990</td>
<td>Each</td>
<td>4(4)</td>
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<tr>
<td>Signal</td>
<td>Countdown Timer Module</td>
<td>$600</td>
<td>$740</td>
<td>$190</td>
<td>$1,930</td>
<td>Each</td>
<td>14(18)</td>
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<tr>
<td>Signal</td>
<td>Pedestrian Signal</td>
<td>$978</td>
<td>$1,479</td>
<td>$126</td>
<td>$10,000</td>
<td>Each</td>
<td>22(33)</td>
</tr>
<tr>
<td>Signal</td>
<td>Signal Face</td>
<td>$490</td>
<td>$430</td>
<td>$130</td>
<td>$800</td>
<td>Each</td>
<td>3(6)</td>
</tr>
<tr>
<td>Signal</td>
<td>Signal Head</td>
<td>$570</td>
<td>$550</td>
<td>$100</td>
<td>$1,450</td>
<td>Each</td>
<td>12(26)</td>
</tr>
<tr>
<td>Signal</td>
<td>Signal Pedestal</td>
<td>$640</td>
<td>$800</td>
<td>$490</td>
<td>$1,160</td>
<td>Each</td>
<td>3(5)</td>
</tr>
<tr>
<td>Signal</td>
<td>Push Button</td>
<td>$230</td>
<td>$350</td>
<td>$61</td>
<td>$2,510</td>
<td>Each</td>
<td>22(34)</td>
</tr>
</tbody>
</table>

(Source: PEDSAFE)
Signals and Signs Countermeasures: PUFFIN Crossing

• PUFFIN: Pedestrian User Friendly Intelligent Intersection

• Pedestrians call a WALK phase, and sensors make sure that sufficient time is provided to cross

(Source: PEDSAFE)
Other Measures

• School Zone Improvement
• Neighborhood Identity
• Speed-Monitoring
• On-Street Parking Enhancements
• Pedestrian/Driver Education
• Police Enforcement
• Automated Enforcement Systems
• Pedestrian Streets/Malls
• Work Zones - Pedestrian Detours
• Pedestrian Safety at Railroad Crossings
• Shared Streets
• Streetcar Planning and Design
Work Zones - Pedestrian Detours

• Detours must comply with ADA requirements

• Detours should deviate as little as possible from desired direction of travel

• Clear and effective signage

Pedestrian detours should seek to provide a safe, convenient, and accessible path that as closely as possible replicates the existing sidewalk(s) or footpath(s).

Source: Flickr - Lynn Friedman (2012)
PEDSAFE Countermeasure Selection Tool
Countermeasure Selection Tool

The selection tool is designed to receive input on several variables from the user in three steps.

1. **Enter the Name of the Location**
   First, enter the location of the site in question. This allows the user to create reports for several different sites and keep the results separated by location. It is used for reporting purposes only and is not stored permanently by the operators of this web site.

2. **Select the Goal of the Treatment**
   Second, one must decide on the goal of the treatment. It may either be to achieve a specific performance objective, such as reduce traffic volumes, or to mitigate a specific type of pedestrian-motor vehicle collision.

3. **Describe the Site**
   Once a specific goal has been selected, the third step is to provide answers to a series of questions related to the geometric and operational characteristics of the site in question. The answers to these questions are used to narrow the list of appropriate countermeasures for a specific goal. For example, if the location of interest were a segment of roadway, or midblock location, then the treatments associated with intersection improvements would not be applicable and thus, would not be included in the results as possible countermeasures.

For any question where the information is not known, an entry of "unknown" will simply retain the countermeasures relevant to the question, and the range of treatments will not be reduced.
Countermeasure Selection Tool

Step 1. Enter the Name of the Location
This allows the user to create reports for several different sites and keep the results separated by location. It is used for reporting purposes only and is not stored permanently by the operators of this web site.

Int. Avenida Corazones/Valle Sur

Proceed to Step 2
Countermeasure Selection Tool

Step 2. Select the Goal of the Treatment

The goal may either be to achieve a specific performance objective, such as reduce traffic volumes, or to mitigate a specific type of pedestrian-motor vehicle collision.

Choose either a performance objective **OR** a crash type.

Name of location: Int. Avenida Corazones/Valle Sur

<table>
<thead>
<tr>
<th>Performance Objectives</th>
<th>Crash Types (click for a brief description)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce Speed of Motor Vehicles</td>
<td>Dart/Dash</td>
</tr>
<tr>
<td>Improve Sight Distance and Visibility</td>
<td>Multiple Threat/Trapped</td>
</tr>
<tr>
<td>Reduce Volume of Motor Vehicles</td>
<td>Unique Midblock</td>
</tr>
<tr>
<td>Reduce Exposure for Pedestrians</td>
<td>Through Vehicle at Unsignalized Location</td>
</tr>
<tr>
<td>Improve Pedestrian Access and Mobility</td>
<td>Bus-Related</td>
</tr>
<tr>
<td>Encourage Walking by Improving Aesthetics</td>
<td>Turning Vehicle</td>
</tr>
<tr>
<td>Improve Compliance with Local Traffic Laws</td>
<td>Through Vehicle at Signalized Location</td>
</tr>
<tr>
<td>Eliminate Behaviors that Lead to Crashes</td>
<td>Walking Along Roadway</td>
</tr>
<tr>
<td>Working or Playing in Roadway</td>
<td>Non-Roadway</td>
</tr>
<tr>
<td>Backing Vehicle</td>
<td>Crossing an Expressway</td>
</tr>
</tbody>
</table>
1. In what type of area is the roadway located?
   - Urban CBD
   - Urban Other
   - Suburban
   - Rural
   - Not Applicable/Unknown

2. What is the functional class of the roadway?
   - Local
   - Collector or Minor Arterial
   - Principal Arterial
   - Not Applicable/Unknown

3. Is the problem at an intersection or midblock (roadway segment) location?
   - Intersection
   - Midblock
   - Not Applicable/Unknown

4. What is the vehicle volume at this location (expressed in terms of average daily traffic (ADT) for the primary roadway)?
   - <10,000
   - >=10,000 and <= 25000
   - > 25000
   - Not Applicable/Unknown

5. Is vehicle speed low or high?
   - <= 45 mph
   - > 45 mph
   - Not Applicable/Unknown

6. What is the number of through travel lanes (both directions)?
   - 2 or fewer lanes
   - 3 or 4 lanes
   - 5 or more lanes
   - Not Applicable/Unknown

7. Is a traffic signal present, being considered, or not an option?
   - Present (Removal not an option)
   - Present (Removal is an option or being considered)
   - Not present (Installation is not an option)
   - Not present (Installation is an option)
   - Not Applicable/Unknown

8. Is the roadway on a transit line/route (bus or rail)?
   - No
   - Yes

9. Is the roadway in a school zone or a school crossing?
   - No
   - Yes

10. Does the roadway contain a railroad crossing?
    - No
    - Yes

11. Is the roadway in a work zone?
    - No
    - Yes
Countermeasure Selection Tool

**Name of location:** Int. Avenida Corazones/Valle Sur  
**Your Crash Type:** Failure to Yield (Unsignalized)  
**Site Description Answers:**  
- **Type of Area:** Suburban  
- **Functional Class:** Collector or Minor Arterial  
- **Intersection or Midblock:** Intersection  
- **Volume:** Low (10,000 ADT)  
- **Speed:** Low (<= 45 mph)  
- **No. of Lanes:** 3 or 4 lanes  
- **Traffic Signal:** Not present (Installation is not an option)  
- **Transit Line/Route:** No, the roadway is not on a transit line/route.  
- **School Zone/Crossing:** No, the roadway is not in a school zone or a school crossing.  
- **Railroad Crossing:** No, the roadway does not contain a railroad crossing.  
- **Work Zone:** No, the roadway is not in a work zone.

Based upon your input, the following countermeasures were found:

**At Crossing Locations**  
- Raised Pedestrian Crossing  
- Crosswalk Enhancement  
- Parking Restrictions  
- Pedestrian Crossing Island  
- Curb Ramp  
- Roadway Lighting  
- Curb Extension

**Roadway Design**  
- Raised Median
Countermeasure Selection
Road Safety Management Process

- Network Screening
- Diagnosis
- Project Selection
- Evaluation
- Appraisal
- Countermeasures
Economic Appraisal

• Comparison of countermeasure benefits to the costs associated to its implementation

• Main objectives:
  • Determine if project is economically justified
  • Determine which project or alternative is more cost-effective

• According to the HSM, there are two types of economic appraisals:
  • Benefit-Cost Analysis (BCA)
  • Cost-Effectiveness Analysis (CEA)

(AASHTO 2009)
Economic Appraisal

• Both methods require quantification of benefits
  • Estimated change in crash frequency
  • Estimated change in crash severity

• In BCA, the “expected change in average crash frequency or severity is:
  1. converted monetary values,
  2. summed, and
  3. compared to the cost of implementing the countermeasures”

• In CEA, the “change in crash frequency is compared directly to the cost of implementing the countermeasure”

(AASHTO 2009)
HSM Economic Appraisals Process

- Countermeasures
  - Quantify Crash Reduction
    - Cost-Effectiveness Analysis
    - Benefit-Costs Analysis
      - Monetary Value of Crash Reduction
      - Project Costs
  - Non-Monetary Considerations
    - Public Perception
    - On-going Projects
    - Community Vision and Environment

(AASHTO 2009)
Outcome of Economic Appraisal Analysis

• Ascending (or descending) ordering according to:
  • Project costs
  • Monetary value of project benefits
  • Number of total crashes reduced
  • Number of fatal and incapacitating injury crashes reduced
  • Number of fatal and injury crashes reduced
  • Net Present Value (NPV)
  • Benefit-Cost Ratio (BCR)
  • Cost-Effectiveness Index
Project Prioritization Methods

• Ranking Procedures
  • Ranking by economic effectiveness measures

  • Incremental cost-benefit ranking
    • Related to the benefit-cost ratio method

• Optimization methods
  • “prioritization consistent with incremental benefit-cost analysis, but consider the impact of budget constraints in creating an optimized project set”
  • “related to the net present value (NPV) method”
Questions or Comments?
References

PART D.
DESIGN OF PEDESTRIAN FACILITIES AND CASE STUDIES
Overview of Part D

• Basic design features of:
  • Pedestrian pathway facilities
  • Markings and signals
  • Lighting

• Case Studies
Pedestrian Facilities

• Sidewalks

• Grade-separated pedestrian crossings

• Curb ramps
Pedestrian Pathways
Americans with Disabilities Act (ADA) of 1990

Title I. Employment

Title II. Public Services

Title III. Public Accommodations and Services Operated by Private Entities

Title IV. Telecommunications

Title V. Miscellaneous Provisions

An equal opportunities law that prohibits the discrimination of people with disabilities
2010 ADA Standards for Accessible Design

• Enforceable accessibility standards that establish the minimum requirements for:

  • **newly designed and constructed** state and local government facilities, public accommodations, and commercial facilities

  • **altered** state and local government facilities, public accommodations, and commercial facilities
People with Disabilities

• Mobility impairments
  • Wheelchair and scooter users
  • Walking-aid users
  • Prosthesis users

• Sensory impairments
  • Visual impairments (e.g., cane users, guide dog users)
  • Hearing impairments
  • Cognitive impairments

(FHWA 1999)
(Source: FHWA 1999)
Pedestrian Access Routes

• “A continuous and unobstructed walkway within a pedestrian circulation path that provides accessibility”

Minimum width: 4 ft. (not including curb)
  - Minimum has to be maintained without obstructions

Passing spaces required in access routes with clear width less than 5 ft.
  - Maximum intervals of 200 ft.
  - 5 ft. × 5 ft.

(Source: FHWA 1999)

(US Access Board 2011)
Pedestrian Crossings

• According to the ADA Accessibility Guidelines (ADAAG):
  “Marked crosswalks shall be 1.8 m (6 ft.) wide minimum.”

• Medians and pedestrian refuge islands
  • Mandated to have a minimum length of 6 ft. in the direction of pedestrian travel
Sec. 12183. New construction and alterations in public accommodations and commercial facilities

“Newly constructed or altered streets, roads, and highways must contain curb ramps or other sloped areas at any intersection having curbs or other barriers to entry from a street level pedestrian walkway.”

“Newly constructed or altered street level pedestrian walkways must contain curb ramps or other sloped areas at intersections to streets, roads, or highways.”

• Resurfacing of existing circulation paths or vehicular ways is an alteration which would trigger ADA compliance
Curb Ramps

• “Ramp runs shall have a running slope not steeper than 1:12”

<table>
<thead>
<tr>
<th>Slope</th>
<th>Maximum Rise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steeper than 1:10 but not steeper than 1:8</td>
<td>3 inches (75 mm)</td>
</tr>
<tr>
<td>Steeper than 1:12 but not steeper than 1:10</td>
<td>6 inches (150 mm)</td>
</tr>
</tbody>
</table>

• “Cross slope of ramp runs shall not be steeper than 1:48”

• Landing area has to be provided at the top of the curb
  • Minimum length: 36 inches
This wheelchair user is maneuvering successfully at a curb ramp because a level landing is provided.

Figure 4-17:
This wheelchair user will have difficulty entering the sidewalk because the curb ramp lacks a landing.

Figure 4-18:
This wheelchair user will have difficulty traveling around the corner because the curb ramp lacks a landing.

(Source: FHWA 1999)
406.2 Counter Slope. Counter slopes of adjoining gutters and road surfaces immediately adjacent to the curb ramp shall not be steeper than 1:20. The adjacent surfaces at transitions at curb ramps to walks, gutters, and streets shall be at the same level.

![Counter Slope of Surfaces Adjacent to Curb Ramps](image)

406.3 Sides of Curb Ramps. Where provided, curb ramp flares shall not be steeper than 1:10.

![Sides of Curb Ramps](image)
Figure 4-50:
When roads are not milled, layers of asphalt build up and make the crossing difficult for wheelchair users and others.

Figure 4-51:
Milling roads from gutter to gutter prevents rapidly changing grades and makes intersections easier for wheelchair users to negotiate.

(Source: FHWA 1999)
Wheelchair ramps shall have a maximum slope of 12:1. The minimum width shall be 1.00 meter. Included as a reference for their design is the one adopted by the Highways Authority and approved by the Federal Highway Administration. Figures 15—K and 15—L.
Curb Ramps

• Exception in the ADA standards:

“In alterations, where there is no landing at the top of curb ramps, curb ramp flares shall be provided and shall not be steeper than 1:12”

• Location of curb ramps
  • Must be located project so that they do not project “into vehicular traffic lanes, parking spaces, or parking access aisles”
Curb Ramps

A minimum of 48 inches of clear space must be provided outside active traffic lanes of the roadway.

(Source: DOJ 2010)
Islands at Crossings

(a) cut through at island

(b) curb ramp at island

Figure 406.7
Islands in Crossings

(Source: DOJ 2010)
Surfaces

• According to the ADA Accessibility Guidelines:
  “The surface of the pedestrian access route shall be firm, stable and slip resistant.”

• Detectable warning surface
  “A standardized surface feature built in or applied to walking surfaces or other elements to warn of hazards on a circulation path”
“Detectable warning surfaces shall contrast visually with adjacent walking surfaces either light-on-dark, or dark-on-light”
Marking and Signals
Figure 4E-2. Pedestrian Intervals

- **Steady**
- **Flashing with countdown**
- **Buffer Interval**

**Pedestrian Signal Display**

- **Walk Interval**
- **Pedestrian Change Interval**

7 seconds MIN.**

Calculated pedestrian clearance time*** (see Section 4E.06)

3 seconds MIN.

**Relationship to associated vehicular phase intervals:**

- Yellow Change Interval = Buffer Interval
- Yellow Change Interval + Red Clearance Interval = Buffer Interval
- Part of Yellow Change Interval + Red Clearance Interval = Buffer Interval
- Red Clearance Interval = Buffer Interval
- Associated Green Interval extends beyond end of Buffer Interval

**Legend**

- **G** = Green Interval
- **Y** = Yellow Change Interval (of at least 3 seconds)
- **R** = Red Clearance Interval
- **Red** = Red because conflicting traffic has been released

---

* The countdown display is optional for Pedestrian Change Intervals of 7 seconds or less.
** The Walk Interval may be reduced under some conditions (see Section 4E.06).
*** The Buffer Interval, which shall always be provided and displayed, may be used to help satisfy the calculated pedestrian clearance time, or may begin after the calculated pedestrian clearance time has ended.

(Source: FHWA 2009)
Pedestrian Intervals and Signal Phases

According to the MUTCD:

“Except as provided in Paragraph 8, the pedestrian clearance time should be sufficient to allow a pedestrian crossing in the crosswalk who left the curb or shoulder at the end of the WALKING PERSON (symbolizing WALK) signal indication to travel at a walking speed of 3.5 feet per second to at least the far side of the traveled way or to a median of sufficient width for pedestrians to wait.”

(FHWA 2009)
Pedestrian Intervals and Signal Phases

• According to the MUTCD:

“Where pedestrians who walk slower than 3.5 feet per second, or pedestrians who use wheelchairs, routinely use the crosswalk, a walking speed of less than 3.5 feet per second should be considered in determining the pedestrian clearance time.”
Accessible Pedestrian Signals

• According to ADAAG:
  “Each crosswalk with pedestrian signal indication shall have an accessible pedestrian signal which includes audible and vibrotactile indications of the WALK interval”

• MUTCD suggests that audible crossing signals when:
  • Crosswalks are skewed
  • Intersection has an irregular geometry
  • Crosswalk longer than 70 ft.
  • Requested by individual with visual impairment

Marking for Pedestrian Network Elements

A) URBAN

B) RURAL

TYPICAL CROSSWALK MARKING

FIG. 15-D

(Source: DTOP)
Lighting
Figure 11. Drawing. Traditional midblock crosswalk lighting layout.

Figure 12. Drawing. New design for midblock crosswalk lighting layout.

(Source: FHWA 2008)
Figure 13. Drawing. Traditional intersection lighting layout.

Figure 14. Drawing. New design for intersection lighting layout for crosswalks.
(Source: FHWA 2008)
Figure 15. Drawing. New design for wide roadway intersection lighting layout for crosswalks.

(Source: FHWA 2008)
Case Studies
Crossing Islands in Eureka, California

• Background:
  • Intersection at Myrtle Avenue/6th Street
  • 70 ft wide street
  • Two lanes in each direction and one two-way left turn lane
  • No marked crosswalk
  • Traffic entered quickly and abruptly

• Problem
  • Pedestrian collisions became a major source of concern after traffic began to increase

(PEDSAFE and Parrot)
Crossing Island in Eureka, California

• Solution:
  • Median island was constructed
  
  • Prior to the installation, a series of temporary traffic controls were implemented to test vehicle movement restrictions

• Result:
  • Intersection went from having the highest collision rate of all intersection in the city to having no collisions in the years following the improvement
Pedestrian Strategy of Richmond, BC, Canada

• Five objectives
  1. Enhance pedestrian facilities
  2. Improve accessibility
  3. Educate on safety
  4. Develop a network of trails
  5. Foster partnerships
Pedestrian Strategy of Richmond, BC, Canada

• Enhanced pedestrian facilities
  • $150,000 per year allocated for improvements
  • Crosswalk lighting upgraded in 4-lane and 3-lane roads
    • Included installation of pedestrian-actuated amber flashers
  • Signage installed to instruct pedestrian on safe crossing procedures

• Improved crosswalks experienced lowest number of pedestrian-related collisions relative to other crosswalks in the city
Global Summary

Part A. The Pedestrian Safety Problem

Part B. Network Screening and Pedestrian Problem Diagnosis

Part C. Pedestrian Safety Countermeasures and Countermeasure Selection

Part D. Design of Pedestrian Facilities and Case Studies
Questions or Comments?
Thank you.

My email: daniel.rodriguez6@upr.edu
References


• PEDSAFE, Parrot S. Crossing Islands: Eureka, California. Available at: http://pedbikesafe.org/PEDSAFE/casestudies_detail.cfm?CS_NUM=73&op=L&subop=I&state_name=California
References


• Source of cartoon illustrations: