DEFINITIONS OF SAFETY MEASURES

Step 1 – Identify Potential Sites

- Measure accident experience by;
  - Total number of crashes
  - Crash density (crashes per mile)
  - Crash rate
    - Crashes per million vehicle miles (segments)
    - Crashes per million entering vehicles (intersection)
Step 1 – Identify Potential Sites

• Measure accident experience by;
  – Number quality control
  – Rate quality control
  – Crash severity
  – Severity index
    • Ratio of injury and fatal crashes to total crashes

Problems Using Crash Counts

• Observed accident counts
  – Common method to rank accident locations
  – Lack of accuracy in accident reports
  – Must be normalized to common basis

• Regression to-the-mean phenomenon
  – An unusually high count is likely to decrease without improvement
  – Such location may not require improvement
Example of Regression to-the-Mean

- Crash data for 1974-76 and 1977 for 1072 San Francisco intersections
- No real change in average accidents per intersection from 1974-77 remained essentially constant at 1.1 accidents/intersection/year

Table A-1. Illustrating the Regression-to-the-Mean Phenomenon

<table>
<thead>
<tr>
<th>Number of intersections</th>
<th>Accidents/intersection in 1974-76</th>
<th>Accidents/year/intersection in 1974-76</th>
<th>Accidents/intersection in 1977</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>266</td>
<td>0</td>
<td>0.25</td>
<td>1.08</td>
<td>Large increase</td>
</tr>
<tr>
<td>218</td>
<td>1</td>
<td>0.33</td>
<td>0.55</td>
<td>67%</td>
</tr>
<tr>
<td>173</td>
<td>2</td>
<td>0.67</td>
<td>0.70</td>
<td>Small increase</td>
</tr>
<tr>
<td>121</td>
<td>3</td>
<td>1.00</td>
<td>1.04</td>
<td>Small increase</td>
</tr>
<tr>
<td>97</td>
<td>4</td>
<td>1.33</td>
<td>1.08</td>
<td>-19%</td>
</tr>
<tr>
<td>70</td>
<td>5</td>
<td>1.67</td>
<td>1.33</td>
<td>-20%</td>
</tr>
<tr>
<td>64</td>
<td>8</td>
<td>2.00</td>
<td>1.56</td>
<td>-22%</td>
</tr>
<tr>
<td>32</td>
<td>7</td>
<td>2.33</td>
<td>2.25</td>
<td>-3%</td>
</tr>
<tr>
<td>29</td>
<td>8</td>
<td>2.67</td>
<td>1.62</td>
<td>-39%</td>
</tr>
</tbody>
</table>

Normalize Crash Counts to Crash Density

- Crash frequency must be normalized to common section length and time period, i.e., crash density
- For example;

<table>
<thead>
<tr>
<th>Location</th>
<th>Section Length</th>
<th>AADT</th>
<th>PDO</th>
<th>Injury A</th>
<th>Injury B</th>
<th>Injury C</th>
<th>F</th>
<th># Acc</th>
<th># Yrs</th>
<th>acc/mi/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.8 mi</td>
<td>4200</td>
<td>12</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>16</td>
<td>3</td>
<td>6.67</td>
</tr>
<tr>
<td>B</td>
<td>1.2 mi</td>
<td>3500</td>
<td>15</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>21</td>
<td>2</td>
<td>8.75</td>
</tr>
<tr>
<td>C</td>
<td>2.2 mi</td>
<td>2400</td>
<td>22</td>
<td>0</td>
<td>1</td>
<td>4</td>
<td>0</td>
<td>27</td>
<td>1.5</td>
<td>8.18</td>
</tr>
</tbody>
</table>
Crash Rates for Highway Sections

- Accident experience for highway sections may be represented as:

\[
\text{Crashes} = \frac{\text{Crashes}}{\text{million veh miles}} = \frac{365(\text{Period})(\text{ADT})(\text{LNG})}{1,000,000}
\]

<table>
<thead>
<tr>
<th>Location</th>
<th>Period, yrs</th>
<th>Section Length, mi</th>
<th>AADT, vpd</th>
<th>Total Accidents</th>
<th>Crash, million veh miles</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3.0</td>
<td>0.8</td>
<td>4200</td>
<td>16</td>
<td>4.35</td>
</tr>
<tr>
<td>B</td>
<td>2.0</td>
<td>1.2</td>
<td>3500</td>
<td>21</td>
<td>6.85</td>
</tr>
<tr>
<td>C</td>
<td>1.5</td>
<td>2.2</td>
<td>2400</td>
<td>27</td>
<td>9.34</td>
</tr>
</tbody>
</table>

Average Crash Rates

<table>
<thead>
<tr>
<th>Location and Road Type</th>
<th>Fatal Accidents</th>
<th>Injury Accidents</th>
<th>Property Damage Only Accidents</th>
<th>Total Accidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rural</td>
<td>Number per MVM</td>
<td>Number per MVM</td>
<td>Number per MVM</td>
<td>Number per MVM</td>
</tr>
<tr>
<td>No Access Control</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 lanes</td>
<td>0.07</td>
<td>0.94</td>
<td>1.39</td>
<td>2.39</td>
</tr>
<tr>
<td>4 or more lanes, undiv.</td>
<td>0.05</td>
<td>0.89</td>
<td>1.55</td>
<td>2.89</td>
</tr>
<tr>
<td>Partial Access Control</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Divided expressway</td>
<td>0.04</td>
<td>0.44</td>
<td>0.76</td>
<td>1.24</td>
</tr>
<tr>
<td>Freeway</td>
<td>0.03</td>
<td>0.27</td>
<td>0.49</td>
<td>0.79</td>
</tr>
</tbody>
</table>

Source: NHI, 2005
Crash Rates for Spot Locations

- Accident experience at intersection locations may be represented as

\[
\frac{\text{Crashes}}{\text{million entering vehicles}} = \frac{\text{Crashes}}{365(\text{Period})(\text{ADT})/1,000,000}
\]

Example: For \( N = 25 \) crashes for 3 years

\[
\text{ADT (N)} = 10,000 \quad \text{ADT (S)} = 9,000 \\
\text{ADT (E)} = 3,500 \quad \text{ADT (W)} = 4,000
\]

\[
\text{Sum(ADT)s} = (10,000 + 9,000 + 3,500 + 4,000) = 26,500
\]

\[
\text{CR} = \frac{N}{\left\{\frac{\text{Sum (ADT)s}}{2}\right\} \times 365 \times 10^{-6}}
\]

\[
\text{CR} = 25/ \{26,500/2\} \times 3 \text{ yrs} \times 365 \times 10^{-6}
\]

\[
\text{CR} = 1.72 \text{ crashes per million entering vehicles}
\]

Source: NHI, 2005
Typical Collision Types at Rural Intersections

<table>
<thead>
<tr>
<th>Type of Control</th>
<th>Accident Type - Percent of Total</th>
<th>Accident Rate (accidents per million entering vehicles)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rear-End</td>
<td>Angle</td>
</tr>
<tr>
<td>Traffic Signal</td>
<td>43</td>
<td>37</td>
</tr>
<tr>
<td>Yield or Stop Sign</td>
<td>29</td>
<td>49</td>
</tr>
</tbody>
</table>

Source: NHI, 2005

Average Intersection Crash Rates

- Average of 1.5 crashes per year for Un-Signalized Intersections in rural areas—recent California analysis*
- Average of 2.5 crashes per year in urban areas

Problems Using Accident Rates

- Accident rates are based on observed counts therefore regression-to-the-mean difficulty applies
- Relationship between accident frequency and ADT is not linear
- Therefore, accident rates at different volume levels may not give a true picture
  - Low ADT likely to give high accident rate

Problem with Using Accident Rates

- Non-linearity
  - Lack of linearity between accident frequency and AADT
Safety Performance Functions  
~ Highway Segments ~

- Level 1: Relationship for previous figure is
  \[ \text{SPF} = \frac{\text{Accidents}}{\text{yr}} = (\text{length}) \times a(AADT)^b \]

- Level 2: General relationships of the form
  \[ \text{SPF} = \frac{\text{Accidents}}{\text{yr}} = (\text{length}) \times a(x_1)^{b_1} (x_2)^{b_2} \ldots (x_n)^{b_n} \]

  where
  \( a, b_1, b_2, \ldots, b_n \) are parameters
  \( x_1, x_2, \ldots, x_n \) are traffic and geometric variables

Safety Performance Functions  
~ Intersections ~

- Level 1
  \[ \text{SPF} = \frac{\text{Accidents}}{\text{yr}} = a(AADT)^b \]

- Level 2
  \[ \text{SPF} = \frac{\text{Accidents}}{\text{yr}} = a(AADT_{\text{MAJ}})^{b_1} (AADT_{\text{MIN}})^{b_2} \]
Crash Reduction Factors (CRF)

- CRF = expected percent decrease in a particular type of crash after a countermeasure is employed

Accident Modification Factor (AMF)

- Base condition of AMF is 1.0
- Example
  - An improvement that decreases accident frequency by 10% would have an AMF = .90
  - An increase in accident frequency of 10% would have AMF = 1.10
Relation of CRF to AMF

- CRF = 1 – AMF
- Other terms
  - CMF (crash modification factor) is same as AMF
  - ARF (accident reduction factors) is same as AMF

Multiple Countermeasures Effects

- Conservative estimate assumes largest CRF is most effective
- This approach is pessimistic
- Cannot warrant adding more than one countermeasure by its form
  - Safest effect not always provided by building just one countermeasure
Compound Multiple Countermeasure Effect

- Aggregate countermeasure effect
  - Multiplication compound effect

  \[
  CRF_{COM} = 1 - (1-CRF_1) (1-CRF_2)
  \]

Example

CRF_1 = 0.20; CRF_2 = .25

\[
CRF_{COM} = 1 - (.2)(.25)
\]

CRF_{COM} = .40

Accident Severity Indicated By

- Fatalities
- Injuries
- Property damage only
Injury Accidents May Be Further Stratified

- Injury type A – incapacitating
- Injury type B – non-incapacitating
- Injury type C – possible injury

Severity Index

Severity index (SI) is the ratio of crashes involving an injury or fatality to total crashes

<table>
<thead>
<tr>
<th>Accident severity level</th>
<th>Proportion of total accidents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Roadway segments</td>
</tr>
<tr>
<td>Fatal and Injury</td>
<td>0.321</td>
</tr>
<tr>
<td>Property damage only</td>
<td>0.879</td>
</tr>
<tr>
<td>TOTAL</td>
<td>1.000</td>
</tr>
</tbody>
</table>

Source: NHI, 2005
FHWA Costs per Accident

<table>
<thead>
<tr>
<th>Accident Type</th>
<th>Cost (Dollars)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PDO</td>
<td>$2,300</td>
</tr>
<tr>
<td>Type C Injury</td>
<td>$22,000</td>
</tr>
<tr>
<td>Type B Injury</td>
<td>$42,000</td>
</tr>
<tr>
<td>Type A Injury</td>
<td>$208,000</td>
</tr>
<tr>
<td>Fatal</td>
<td>$3,000,000</td>
</tr>
</tbody>
</table>

Source: Highway Safety Manual

Traffic Crash Costs:

<table>
<thead>
<tr>
<th>AIS Level Severity</th>
<th>Descriptor</th>
<th>Cost Per Injury (Dollars)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Property Damage Only</td>
<td>(A)</td>
<td>65,000</td>
</tr>
<tr>
<td>AIS 3</td>
<td>Serious Injury (C)</td>
<td>175,000</td>
</tr>
<tr>
<td>AIS 4</td>
<td>Severe (B)</td>
<td>565,000</td>
</tr>
<tr>
<td>AIS 5</td>
<td>Critical (A)</td>
<td>2,290,000</td>
</tr>
<tr>
<td>AIS 6</td>
<td>Fatal</td>
<td>3,000,000</td>
</tr>
</tbody>
</table>

Source: NHI, 2005
Safety Benefits

- Annual safety benefits =
  \[ CRF_F \times (\text{fatal acc.}) \times \text{fatal } \$
  + CRF_I \times (\text{injury acc.}) \times \text{injury } \$
  + CRF_{PDO} \times (\text{PDO acc.}) \times \text{PDO } \$
\]

OR

- Annual safety benefits =
  \[ CRF \times (\text{total acc.}) \times \text{weighted value accident} \]

PSI_{INDEX} Approach

PSI_{INDEX} = CRF_F \times (\text{fatal accident})

+ CRF_I \times (\text{injury accident})

+ CRF_{PDO} \times (\text{PDO accident})