CE576: Highway Design and Traffic Safety

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Two-Lane Rural Highway Segments

What should you expect would be the safety and operational influence of cross sectional elements?

<table>
<thead>
<tr>
<th>Cross Sectional Elements</th>
<th>Crashes</th>
<th>Operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lane Width</td>
<td>Head-on</td>
<td>Capacity</td>
</tr>
<tr>
<td></td>
<td>Wider is “better”</td>
<td>Wider means “faster”</td>
</tr>
<tr>
<td>Shoulder Width</td>
<td>Run-off-Road</td>
<td>Capacity</td>
</tr>
<tr>
<td></td>
<td>Wider is “better”</td>
<td>Functionality (peds, bikes, emergency stops, capacity, maintenance)</td>
</tr>
<tr>
<td>Sideslope</td>
<td>Run-off-road (severity)</td>
<td>Maintenance</td>
</tr>
<tr>
<td></td>
<td>Flatter is better</td>
<td>Flatter is better</td>
</tr>
<tr>
<td>Clear Zone</td>
<td>Run-off-road (frequency and severity)</td>
<td>Horizontal sight distance</td>
</tr>
</tbody>
</table>

Predicting Crash Frequency for Two-Lane Rural Highway Segments

Cross Sectional Elements

Two-Lane Rural Highway Segments

Functions of shoulders in a rural environment

- Clear zone (recovery)
- Highway Capacity
- Clear zone (horizontal sight distance)
- Store vehicles in emergency
- Pedestrians, bicyclists
- Protection for turns off the roadway
- Provide pavement support
- Store snow
- Provide space for maintenance activities
- Enforcement activities

Two-Lane Rural Highway Segments
**Key Findings of FHWA Cross Section Study on Two-Lane Hwys (Zegeer)**

- Traffic volume influences crash rate
- Both lane and shoulder width have influence
- Roadside Hazard *next biggest* influence on crashes
- Alignment affects cross section crashes (terrain is surrogate for alignment)

**Two-Lane Rural Highway Segments**

**Crash Severity for Two-Lane Rural Highways**

<table>
<thead>
<tr>
<th>Crash Severity Level</th>
<th>Percentage of Total Roadway Segment Crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatal</td>
<td>1.3</td>
</tr>
<tr>
<td>Incapacitating Injury</td>
<td>5.4</td>
</tr>
<tr>
<td>Nonincapacitating injury</td>
<td>10.9</td>
</tr>
<tr>
<td>Possible injury</td>
<td>14.5</td>
</tr>
<tr>
<td>Total fatal plus injury</td>
<td>32.1</td>
</tr>
<tr>
<td>Property damage only</td>
<td>67.9</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
</tr>
</tbody>
</table>

**Rural 2 Lane Highway Segment Severity Ratio = 32.1% for Injury + Fatal Crashes**

**HSM Crash Prediction: 18 Steps for Two-Lane Rural Roadways**

- Rural Area Definition:
  - Places outside urban boundaries
  - Populations of 5,000 persons, or less
- Applicable to:
  - Existing Roadways
  - Design Alternatives for existing or new roadways

**Predicting Crash Frequency Performance - Analysis Sections**

- Organizing information for Safety Analysis:
  - Separate project lengths (and crashes) into homogeneous units:
    - Average daily traffic (AADT) volume (vehicles/day)
      - Lane width (ft)
      - Shoulder width (ft)
      - Shoulder Type
    - Driveway Density (driveways per mile)
    - Roadside Hazard Rating
    - Beginning/End of Horizontal Curves
    - Beginning/End of Segments on Grade (>3%)
Subdividing Roadway Segments

- Homogeneous Roadway Segments:
  - Lane Width
  - Shoulder Width

### Lane Width

<table>
<thead>
<tr>
<th>Measured Lane Width</th>
<th>Rounded Lane Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.2 ft or less</td>
<td>9 ft or less</td>
</tr>
<tr>
<td>9.3 ft to 9.7 ft</td>
<td>9.5 ft</td>
</tr>
<tr>
<td>9.8 ft to 10.2 ft</td>
<td>10 ft</td>
</tr>
<tr>
<td>10.3 ft to 10.7 ft</td>
<td>10.5 ft</td>
</tr>
<tr>
<td>10.8 ft to 11.2 ft</td>
<td>11 ft</td>
</tr>
<tr>
<td>11.3 ft to 11.7 ft</td>
<td>11.5 ft</td>
</tr>
<tr>
<td>11.8 ft or more</td>
<td>12 ft or more</td>
</tr>
</tbody>
</table>

### Shoulder Width

<table>
<thead>
<tr>
<th>Measured Shoulder Width</th>
<th>Rounded Shoulder Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5 ft or less</td>
<td>0 ft</td>
</tr>
<tr>
<td>0.6 ft to 1.5 ft</td>
<td>1 ft</td>
</tr>
<tr>
<td>1.6 ft to 2.5 ft</td>
<td>2 ft</td>
</tr>
<tr>
<td>2.6 ft to 3.5 ft</td>
<td>3 ft</td>
</tr>
<tr>
<td>3.6 ft to 4.5 ft</td>
<td>4 ft</td>
</tr>
<tr>
<td>4.6 ft to 5.5 ft</td>
<td>5 ft</td>
</tr>
<tr>
<td>5.6 ft to 6.5 ft</td>
<td>6 ft</td>
</tr>
<tr>
<td>6.6 ft to 7.5 ft</td>
<td>7 ft</td>
</tr>
<tr>
<td>7.6 ft or more</td>
<td>8 ft or more</td>
</tr>
</tbody>
</table>

**HSM Crash Prediction Method**

Three Basic Elements:

1. Safety Performance Functions (SPF) Equations
   - Predict safety performance for set base conditions
2. Crash Modification Factors (CMFs)
   - Adjust predicted safety performance from base conditions to existing/proposed conditions
   - Are greater or less than 1:
     - < 1.0 -- lower crash frequency
     - > 1.0 -- increased crash frequency
3. Calibration, $C_r$ or $C_i$
   - Accounts for local conditions/data

Total estimated crashes within the limits of the roadway being analyzed:

$$N_{total} = \sum N_{predicted-rs} + \sum N_{predicted-int}$$

- $N_{total}$ = Total expected number of crashes within the limits of the roadway facility
- $\sum N_{predicted-rs}$ = Expected crash frequency for all roadway segments (sum of individual segments)
- $\sum N_{predicted-int}$ = Expected crash frequency for all intersections (sum of individual intersections)
Roadway Segment Prediction Model

\[ N_{\text{predicted-rs}} = N_{\text{spf-rs}} \times (\text{CMF}_{1r} \ldots \text{CMF}_{xr}) \ C_r \]

Where:
- \( N_{\text{predicted-rs}} \) = predicted average crash frequency for an individual roadway for a specific year (crashes per year)
- \( N_{\text{spf-rs}} \) = predicted average crash frequency for base conditions for an individual roadway segment (crashes per year)
- \( \text{CMF}_{1r} \ldots \text{CMF}_{xr} \) = Crash Modification Factors for individual design elements
- \( C_r \) = calibration factor

Safety Performance Function (SPF)

\[ N_{\text{spf-rs}} = (AADT_n) (L) (365) (10^{-6}) e^{-0.312} \]

Where:
- \( N_{\text{spf-rs}} \) = predicted total crash frequency for a roadway segment for base conditions, crashes per year
- \( AADT_n \) = average annual daily two-way traffic volume for specified year \( n \) (veh/day)
- \( L \) = length of roadway segment (miles)

Base Conditions for Rural Two-Lane Roadway Segments (CMF = 1.0)

- Lane Width: 12 feet
- Shoulder Width: 6 feet
- Shoulder Type: Paved
- Roadside Hazard Rating: 3
- Driveway Density: \( \leq 5 \) driveways/mi
- Grade: \( \leq 3\% \) (absolute value)
- Horizontal Curvature: None
- Vertical Curvature: None
- Centerline rumble strips: None
- TWLTL, climbing, or passing lanes: None
- Lighting: None
- Automated Enforcement: None

Applying SPF for Base Conditions – Example:

\[ N_{\text{spf-rs}} = (AADT_n) (L) (365) (10^{-6}) e^{-0.312} \]

2-lane state highway connecting a US marked route to a primary State marked route in a rural county;

Where:
- AADT = 3,500 vpd
- Length = 26,485 feet = 5.02 miles
 Applying SPF for Base Conditions – Example:

Where:
AADT = 3,500 vpd
Length = 26,485 feet = 5.02 miles

\[ N_{spf-rs} = (\text{AADT}_n) \ (L) \ (365) \ (10^{-6}) \ e^{-0.312} \]
\[ N_{spf-rs} = (3,500) \ (5.02) \ (365) \ (10^{-6}) \ e^{-0.312} \]
\[ = (3,500) \ (5.02) \ (365) \ (10^{-6}) \ (0.7320) \]
\[ = 4.69 \text{ crashes per year} \]