Interchange Deceleration Lane Design Based on Naturalistic Driving Speed and Deceleration Rates

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Outline

1. Problem and Objectives
2. Method
3. Analysis Results
4. Conclusions & Applications

Problem – Crash Rates

Deceleration lanes account for < 1% of freeway miles

<table>
<thead>
<tr>
<th>Crash Rate (MVMT)</th>
<th>Deceleration</th>
<th>Acceleration</th>
<th>Freeway</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.68</td>
<td>0.16</td>
<td>0.59</td>
</tr>
</tbody>
</table>

(NCHRP, 2012)

Problem – Crash Types

Deceleration Lane Crashes

- Rear-End: 42%
- Other: 27%
- Collision with Fixed Object: 31%

Diverging Area Crashes

- 0.31% fatal
- Significantly higher than merging area

The Green Book

- The *Green Book* provides the minimum lengths of deceleration lanes.
- The length recommendations provided by the 2011 edition are similar to the documents published in 1965, which were based on the data collected in the 1930s and had not been updated.

Why NDS

- Driver behavior
- Daily trips
- Details of the driver, vehicle, and surroundings
- Previous studies relied primarily on radar data and computer simulations

Previous studies do not utilize NDS data

Fitzpatrick et al., 2012; Abdelnaby, 2014

Schagen et al., 2011
Objectives: To determine…

- Speed distribution on deceleration lane and off-ramp
  - For diamond and partial cloverleaf (parclo) interchanges
- Deceleration behavior
  - By analyzing deceleration rates and average brake pedal usage
- Updated minimum deceleration lane length
  - To utilize speed and deceleration distribution

Method

Site Description

- What do the sites look like?
- What data can be analyzed?
- Speed Analysis
  - Speed and deceleration rate distribution
- Deceleration Analysis

Site Description

<table>
<thead>
<tr>
<th>Site</th>
<th>Design</th>
<th>Lane Design</th>
<th>Taper Length (ft)</th>
<th>Deceleration Lane Length (ft)</th>
<th>Off-Ramp Length (ft)</th>
<th>AASHTO Minimum Deceleration Length (ft)</th>
<th>Design Status</th>
<th>Number of Trips</th>
</tr>
</thead>
<tbody>
<tr>
<td>Florida I-75</td>
<td>3 Sites</td>
<td>Parallel design</td>
<td>Diamond &amp; parclo</td>
<td>Exit 384 (1)</td>
<td>Exit 341 (2)</td>
<td>Exit 265 (3)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Data Cleansing

- Data was obtained from NDS dataset:
  - Video
  - Time series report: speed (km/h), pedal status (0 or 1)
- 261 trips containing enough information to perform the analysis.

Polynomial Regression

\[
\nu = \beta_0 + \beta_1 L + \beta_1 L^2 + \cdots + \beta_n L^n + \varepsilon
\]  

where,

- \(L\) = a distance from the starting point of the taper along the deceleration lane and off-ramp (ft),
- \(\nu\) = vehicle speed (mph),
- \(\beta_i\) = estimated parameters,
- \(\varepsilon\) = the error of the specification.

- The statistical computing software R
- The fitted model with the smallest residual standard error was considered.

Gill et al., 1981
Deceleration Distance

\[ D = \frac{v^2 - v_f^2}{2d} \]  

(2)

where,  
\[ D \] = deceleration distance (ft),  
\[ v \] = initial speed (ft/s),  
\[ v_f \] = final speed (ft/s),  
\[ d \] = deceleration rate (ft/s²).

El-Basha et al., 2007

Results, Conclusions & Applications

<table>
<thead>
<tr>
<th>Speed Distribution-Diamond</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Graph" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Speed Distribution-Parclo</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image2" alt="Graph" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Speed Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image3" alt="Graph" /></td>
</tr>
</tbody>
</table>

El-Basha et al., 2007

Minimum Deceleration Lane Length

- A new method to determine the minimum length

Speed Distribution

- Diamond interchange: One-lane exit with parallel design
  - \[ v_1 = -1.639 \times 10^{-8} L_1^2 + 4.465 \times 10^{-7} L_1 - 4.541 \times 10^{-5} L_1 + 72.67 \]
  - \[ v_2 = -1.670 \times 10^{-5} L_2^2 + 2.768 \times 10^{-5} L_2 - 2.663 \times 10^{-4} L_2 + 68.32 \]

- Parclo interchange: Two-lane exit with parallel design
  - \[ v_{3-Lane} = -3.939 \times 10^{-11} L_3^4 + 2.347 \times 10^{-10} L_3^3 - 4.778 \times 10^{-9} L_3^2 + 68.52 \]
  - \[ v_{2-2lane} = 2.881 \times 10^{-10} L_2^3 - 2.318 \times 10^{-9} L_2^2 - 6.957 \times 10^{-8} L_2 + 65.16 \]

- Left Off Ramp
  - \[ v_{3-Lane} = -1.007 \times 10^{-10} L_3^3 + 2.366 \times 10^{-10} L_3^2 - 2.195 \times 10^{-9} L_3^1 + 9.955 \times 10^{-9} L_3^0 \]
  - \[ -2.200 \times 10^{-6} L_2^3 + 1.998 \times 10^{-6} L_2^2 - 6.443 \times 10^{-5} L_2^1 + 59.74 \]

- Right Off Ramp
  - \[ v_{3-Lane} = -6.431 \times 10^{-12} L_3^5 + 8.493 \times 10^{-12} L_3^4 - 4.032 \times 10^{-12} L_3^3 \]
  - \[ + 7.665 \times 10^{-9} L_3^2 + 6.533 \times 10^{-7} L_3^1 - 2.082 \times 10^{-5} L_3^0 + 55.62 \]
### Speed Reduction

<table>
<thead>
<tr>
<th>Site</th>
<th>Speed (mph)</th>
<th>Speed Reduction Percent</th>
<th>Length of Off-Ramp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location 1-1358</td>
<td>52.07</td>
<td>63.37</td>
<td>63.37</td>
</tr>
<tr>
<td>Location 2-2132</td>
<td>69.32</td>
<td>66.82</td>
<td>3.14</td>
</tr>
<tr>
<td>Location 3-1606</td>
<td>60.32</td>
<td>57.86</td>
<td></td>
</tr>
<tr>
<td>Location 4-2268</td>
<td>60.81</td>
<td>57.81</td>
<td></td>
</tr>
</tbody>
</table>

*Note: Speed reduction percentage of speed reduction based on speed reduction from deceleration lane start point to the off-ramp end.*

### Deceleration Rate

<table>
<thead>
<tr>
<th>Deceleration Rate (ft/s²)</th>
<th>Deceleration Lane (d_D)</th>
<th>Off-Ramp (d_R)</th>
<th>GIll Decel Rate (°/s²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location 1: 1-75 SW Archer Rd</td>
<td>-1.99, -0.55, -1.77, -3.3</td>
<td>-1.99, -0.59, -2.38, -3.8</td>
<td>-5.41</td>
</tr>
<tr>
<td>Location 2: 1-75 SW County Highway</td>
<td>-1.72, -0.67, -1.74, -2.1</td>
<td>-1.72, -0.67, -2.30, -3.1</td>
<td>-5.41</td>
</tr>
<tr>
<td>Location 3: 1-75 Fawler</td>
<td>-0.31, -0.14, -0.29, -0.4</td>
<td>-0.31, -0.14, -0.30, -0.5</td>
<td>-4.52</td>
</tr>
</tbody>
</table>

A NEGATIVE deceleration rate indicates deceleration in the table.

### Minimum Deceleration Lane Length

<table>
<thead>
<tr>
<th>Study Location</th>
<th>Proposed Minimum Deceleration Lane Length (ft)</th>
<th>Speed at the 1st Controlling Feature (mi/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location 1: 1-75 SW Archer Rd</td>
<td>SCa1</td>
<td>600</td>
</tr>
<tr>
<td>Location 2: 1-75 SW County Highway</td>
<td>219B</td>
<td>500</td>
</tr>
<tr>
<td>Location 3: 1-75 Fawler</td>
<td>SCa1</td>
<td>500</td>
</tr>
</tbody>
</table>

*Note: SCa1 indicates that the deceleration lane is not necessary.*

### Conclusions

- Drivers were not effectively using deceleration lane as would be expected.
  - Speed reduction:
    - Deceleration lane: 20%-25%
    - Off-ramp: 75%-80%
  - The operating speeds on the off-ramp were not significantly affected by the advisory speed limit sign:
    - 35 mph advisory speed limit: 54.61 mph
    - 55 mph advisory speed limit: 58.78 mph
## Conclusions

- The effective deceleration segment was on the off-ramp rather than deceleration lane.
  - Brake pedal usage:
    - Deceleration lane: 38.99%
    - Off-ramp: 73.19%
  - Deceleration rates lower than those assumed by *Green Book*
- The key assumptions in *Green Book* should be considered for updating.
  - The operating speeds when entering the deceleration lane and off-ramp
  - Deceleration rate with brakes

## Questions and Comments