Safety Implications of Managed Lane Cross Sectional Elements
(Buffer Width vs. Shoulder Width vs. Lane Width)

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What does Managed Lane mean?

• The term refers to freeway lanes whose operations are actively managed.

• Examples of Managed Lanes:
  ▪ HOV lanes
  ▪ HOT lanes
  ▪ Reversible Lanes
Project Objectives

• Evaluate managed lane facilities that are currently used in the U.S. to inform decisions about lane, buffer, and shoulder (inside and outside) widths.

• To assess the safety impacts of using of narrow widths.
Previous Findings – Freeways

• Freeway crash prediction equations available in *Highway Safety Manual*

• Reduction in freeway shoulder width → increase crashes

• Reduction in freeway lane width → increase crashes

• Increase in crashes may be offset if reductions are done to increase number of freeway lanes
Previous Findings – Managed Lanes

• Florida study → crash prediction equations for HOV / HOT lanes
  ▪ Left shoulder width and 2-3 ft buffer (10 lane freeways) found to influence safety

• California study
  ▪ Wider HOV lane width associated with fewer HOV crashes
  ▪ Wider left shoulder width associated with fewer HOV crashes

• Texas study (narratives) identify following contributors
  ▪ Reduced HOV cross section, location of GP ramps, speed differential
Identify Potential Sites

• Gather **geometric** information for a sample of existing managed lanes
  - Review aerial photographs of several sites in several states (focus on states with available crash data)
  - Key variables
    - Number of managed lanes
    - Managed lane – left shoulder width
    - Managed lane – lane width
    - Separation – barrier, buffer, and width
# Potential Site Findings

<table>
<thead>
<tr>
<th>Variable</th>
<th>Range or Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>State</td>
<td>California, Colorado, Florida, Georgia, Minnesota, New Jersey, New York, Tennessee, Texas, Utah, Virginia, Washington</td>
</tr>
<tr>
<td>Sites</td>
<td><strong>Random</strong> selections within the states</td>
</tr>
<tr>
<td>Buffer</td>
<td>Flush (markings only), Barrier, or Pylons</td>
</tr>
<tr>
<td>#Lanes</td>
<td>1, 2, or 3 (focused on 1 lane facilities)</td>
</tr>
<tr>
<td>Lane Width</td>
<td>typically either 11 or 12 ft</td>
</tr>
<tr>
<td>Buffer (flush)</td>
<td>typically around 1 to 2 ft</td>
</tr>
<tr>
<td>Buffer (pylons)</td>
<td>typically around 4 to 5 ft</td>
</tr>
<tr>
<td>Shoulder</td>
<td>typically around 7 ft (extensive variability)</td>
</tr>
</tbody>
</table>
Crash Data

• Determine availability of suitable crash data
  ▪ Highway Safety Information System databases
    – California
    – Washington
    – Minnesota
    – North Carolina
    – Ohio
    – Illinois
  ▪ Texas
Crash Data – Promising Leads

- Texas (2010-2014)
  - Includes variables that have HOV or Managed Lanes descriptors
  - Provide lat / long – improved ability to locate crash on facility
  - Crash narratives could be available
### Crash Data – Promising Leads

**California (2007-2011)**

- Lots of managed lanes

- Crash frequencies in table represent a subset of the state →

<table>
<thead>
<tr>
<th>Location Type</th>
<th>Code</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does Not Apply</td>
<td>-</td>
<td>329</td>
</tr>
<tr>
<td>Unknown Type</td>
<td>---</td>
<td>52239</td>
</tr>
<tr>
<td>Beyond Median Or Barrier Stripe - Driver’s Left</td>
<td>A</td>
<td>999</td>
</tr>
<tr>
<td>Beyond Shoulder - Driver’s Left</td>
<td>B</td>
<td>11513</td>
</tr>
<tr>
<td>Left Shoulder Area</td>
<td>C</td>
<td>286</td>
</tr>
<tr>
<td>Left Lane</td>
<td>D</td>
<td>77156</td>
</tr>
<tr>
<td>Interior Lanes</td>
<td>E</td>
<td>94726</td>
</tr>
<tr>
<td>Right Lane</td>
<td>F</td>
<td>63785</td>
</tr>
<tr>
<td>Right Shoulder Area</td>
<td>G</td>
<td>1822</td>
</tr>
<tr>
<td>Beyond Shoulder - Driver’s</td>
<td>H</td>
<td>11023</td>
</tr>
<tr>
<td>Gore Area</td>
<td>I</td>
<td>134</td>
</tr>
<tr>
<td>Other</td>
<td>J</td>
<td>2110</td>
</tr>
<tr>
<td><strong>HOV Lane</strong></td>
<td>V</td>
<td>15257</td>
</tr>
<tr>
<td><strong>HOV Buffer</strong></td>
<td>W</td>
<td>437</td>
</tr>
<tr>
<td>Grand Total</td>
<td></td>
<td>331816</td>
</tr>
</tbody>
</table>

Business Sensitive 10
Site Selection

• Focus on sites with 1 managed lane (rather than 2 lanes)
• Eliminate sites w/ reversible ops or concrete barrier separation
• Prefer managed lanes that are operational 24/7
• Want range of buffer widths, shoulder widths, lane widths
Managed Lane Sections

• Identify locations where the buffer (markings) change

• Classify as non-weaving or “weaving” sections

• Weaving =
  ▪ Ramps
  ▪ Opening in pavement markings
Managed Lane Geometrics

- Lane width (inside markings)
- Shoulder width
- Buffer type and width (includes markings)
General Purpose Lanes

- Number of lanes
- Average lane width (ft)
- Right shoulder width (ft)
- Number of entrance ramps
- Number of exit ramps
- Number of weaving (auxiliary lanes)
- Posted speed limit (mph)
Limits of Sections

• Identify the beginning and ending points for each section
• Texas – use lat / long plus road name to assign crashes to section
• California – use mile post plus road name to assign crashes to section
Other Items

• Posted Speed Limit (mph)
• Direction of travel (E, W, N, S, etc.)
  ▪ Used to match crashes
  ▪ Need obvious plus reasonable directions
• Earliest date ML existence can be verified
  ▪ Used in eliminating crashes that occurred before ML installed
## California Sites (All Flush)

<table>
<thead>
<tr>
<th>Highway - Dir</th>
<th>Total Len (mi)</th>
<th>Average LSW (ft)</th>
<th>Average ML (ft)</th>
<th>Average Buffer (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>105-EB</td>
<td>9.4</td>
<td>10.8</td>
<td>10.9</td>
<td>4.8</td>
</tr>
<tr>
<td>105-WB</td>
<td>13.4</td>
<td>10.7</td>
<td>11.6</td>
<td>5</td>
</tr>
<tr>
<td>134-EB</td>
<td>8.1</td>
<td>3.5</td>
<td>11.2</td>
<td>1.5</td>
</tr>
<tr>
<td>134-WB</td>
<td>7.6</td>
<td>1.3</td>
<td>11.2</td>
<td>1.6</td>
</tr>
<tr>
<td>210-EB</td>
<td>19.1</td>
<td>7</td>
<td>11.3</td>
<td>3.2</td>
</tr>
<tr>
<td>210-WB</td>
<td>14.2</td>
<td>7.9</td>
<td>11.4</td>
<td>3.4</td>
</tr>
<tr>
<td>405-NB</td>
<td>29.7</td>
<td>4</td>
<td>10.7</td>
<td>2.6</td>
</tr>
<tr>
<td>405-SB</td>
<td>26.6</td>
<td>4.1</td>
<td>11.1</td>
<td>3.5</td>
</tr>
<tr>
<td><strong>Total or Range</strong></td>
<td><strong>128.0</strong></td>
<td><strong>1-33</strong></td>
<td><strong>10-12</strong></td>
<td><strong>1-12</strong></td>
</tr>
</tbody>
</table>
California Crash Data Reduction

• 2007 to 2011 (5 years)
• Data cleaning and filtering:
  ▪ Remove crashes with no clear direction of travel
  ▪ Remove crashes that occurred before managed lane was installed (i.e., outside the period of time with valid ML geometric data)
• Dataset of 19,388 freeway crashes for analysis
• Of these freeway crashes, 1,995 crashes were coded as “HOV Lane” or “HOV Buffer”
## Texas Sites

<table>
<thead>
<tr>
<th>F or P</th>
<th>ST-Cl-Hwy-DIR</th>
<th>Len (mi)</th>
<th>LSW (ft)</th>
<th>Lane (ft)</th>
<th>Buffer (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>TX-DA-75-NB</td>
<td>11.0</td>
<td>3-3.5</td>
<td>11-11.5</td>
<td>4</td>
</tr>
<tr>
<td>P</td>
<td>TX-DA-75-SB</td>
<td>11.0</td>
<td>2-2</td>
<td>11.5-11.5</td>
<td>4</td>
</tr>
<tr>
<td>P</td>
<td>TX-DA-635-EB</td>
<td>8.1</td>
<td>2-3.5</td>
<td>10-10.5</td>
<td>4-6</td>
</tr>
<tr>
<td>P</td>
<td>TX-DA-635-WB</td>
<td>7.4</td>
<td>1-2.5</td>
<td>10-10.5</td>
<td>5.5</td>
</tr>
<tr>
<td>P</td>
<td>TX-HO-10-EB</td>
<td>2.3</td>
<td>17.5-18</td>
<td>13-13.5</td>
<td>5-5.5</td>
</tr>
<tr>
<td>P</td>
<td>TX-HO-10-WB</td>
<td>1.9</td>
<td>17.5-17.5</td>
<td>12.5-12.5</td>
<td>5.5</td>
</tr>
<tr>
<td>F</td>
<td>TX-HO-59S-NB</td>
<td>7.3</td>
<td>10-13</td>
<td>11-12</td>
<td>1.5-5</td>
</tr>
<tr>
<td>F</td>
<td>TX-HO-59S-SB</td>
<td>6.0</td>
<td>9-12</td>
<td>11-12</td>
<td>2-5</td>
</tr>
<tr>
<td>F</td>
<td>TX-HO-290-NB</td>
<td>2.2</td>
<td>1.5-4</td>
<td>10.5-11.5</td>
<td>1.5</td>
</tr>
<tr>
<td>F</td>
<td>TX-HO-290-SB</td>
<td>3.2</td>
<td>1.5-1.5</td>
<td>11-11</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total or Range</strong></td>
<td><strong>60.4</strong></td>
<td><strong>1-18</strong></td>
<td><strong>10-13.5</strong></td>
<td><strong>1.5-6</strong></td>
<td></td>
</tr>
</tbody>
</table>
Texas Crash Data Reduction

- 2009 to 2014 (6 years)
- Data cleaning and filtering:
  - Remove crashes with no clear direction of travel
  - Remove crashes that occurred before managed lane was installed (i.e., outside the period of time with valid ML geometric data)
  - Remove crashes not explicitly coded on freeway routes and explicitly coded as occurred on frontage roads
- Dataset of 8,521 freeway crashes for analysis
- Of these freeway crashes, **only 47 crashes** were coded as “HOV” or “Managed Lane” (ML crashes probably under-reported in Texas)
Evaluations

• Managed-lane related crashes → California only
  ▪ All severity levels
  ▪ Fatal and injury severity levels
  ▪ AADT = volume on managed lane

• Freeway crashes → both California and Texas
  ▪ All severity levels
  ▪ Fatal and injury severity levels
  ▪ AADT = volume on freeway
Findings – California, Managed-Lane Crashes, Fatal & Injury Severity

- Several models considered
- In most cases, only a few of the variables were significant
- When managed lane elements included (shoulder, lane, buffer), only left shoulder width significant
- When ML envelope included, it was significant
Closer Look at Buffers in California

![Graph showing the relationship between flush buffer width and MLB crashes per year per mile per 1000 vehicles per day.](image)
## Summary of Key Findings

<table>
<thead>
<tr>
<th>State or HSM</th>
<th>Severity</th>
<th>Location of Crash</th>
<th>Crash Reduction when widening Managed Lane Envelope by 1 ft</th>
<th>Highway Safety Manual: Reduction per Additional Foot of…</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lane</td>
</tr>
<tr>
<td>California</td>
<td>Fatal &amp; Injury</td>
<td>Managed-Lane or Buffer</td>
<td>4.5%</td>
<td>Not available</td>
</tr>
<tr>
<td>HSM</td>
<td>Fatal &amp; Injury</td>
<td>Freeway</td>
<td>Not available</td>
<td>About 3.9%</td>
</tr>
<tr>
<td>California</td>
<td>All</td>
<td>Freeway</td>
<td>2.0%</td>
<td>Not available</td>
</tr>
<tr>
<td>Texas</td>
<td>All</td>
<td>Freeway</td>
<td>2.8%</td>
<td>Not available</td>
</tr>
</tbody>
</table>
Summary of Key Findings

- Managed lane or flush buffer crashes (CA)
  - 4.5% reduction in KAB crashes for each additional foot of managed lane envelope.

- No managed lanes crash reduction in the HSM, however, the HSM does contain other applicable estimates
  - 3.9% crash reduction for each additional foot of freeway lane
  - 1.7% reduction per each additional foot of inside shoulder

- All freeway and all severity crashes
  - Similar reductions in crashes for each additional foot of managed-lane envelope:
    - California, 2.0%
    - Texas 2.8%
Synthesis of Operational Aspects and Safety Implications of Reduced Cross Sectional Elements
(Buffer Width vs. Shoulder Width vs. Lane Width)

DISCUSSION

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