Using Event Based Data to Assess Vehicle Pedestrian Crash Risk in the Absence of All-Red Phase at Signalized Intersections.

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23rd Annual Transportation Research Conference, May 23-24, 2012
Objectives

Ø Retting et al. (2002): 37% relative reduction in the pedestrian and bicycle crashes by modifying the traffic signal change.

Ø Can Smart Signal data help in pedestrian safety decision making at a signalized intersection?

Ø How effective is the signal timing (particularly “All-Red”) phase in reducing potential crashes.
Selected Intersections

• TH 55/Boone Ave WB (speed limit = 55 mph)
• TH 55/Boone Ave NB (speed limit = 30 mph)
• Eden prairie TH 312/5 ramp (speed limit = 30 mph)
• TH 55/Winnetka SB (speed limit = 30 mph)
• TH 55/Winnetka NB (speed limit = 30 mph)

Note: Not all intersections being suitable for our study (For example, intersections with large setback distance to target lane.)
**TABLE 1 Characteristics of the sites chosen for our study**

<table>
<thead>
<tr>
<th>Site</th>
<th>Approach</th>
<th>length of intersection (feet)</th>
<th>speed limit (mph)</th>
<th>no. of cycles</th>
<th>set back distance (feet)</th>
<th>all-red phase (secs)</th>
<th># of* events</th>
</tr>
</thead>
<tbody>
<tr>
<td>1(a)</td>
<td>NB</td>
<td>153.5</td>
<td>30</td>
<td>160</td>
<td>7</td>
<td>2.5</td>
<td>7</td>
</tr>
<tr>
<td>1(b)</td>
<td>WB</td>
<td>169</td>
<td>55</td>
<td>160</td>
<td>7</td>
<td>1.5</td>
<td>28</td>
</tr>
<tr>
<td>2(a)</td>
<td>SB</td>
<td>146</td>
<td>30</td>
<td>162</td>
<td>8</td>
<td>3.0</td>
<td>10</td>
</tr>
<tr>
<td>2(b)</td>
<td>NB</td>
<td>135</td>
<td>30</td>
<td>162</td>
<td>8</td>
<td>3.0</td>
<td>16</td>
</tr>
<tr>
<td>3</td>
<td>EB</td>
<td>140</td>
<td>30</td>
<td>305</td>
<td>7</td>
<td>3.0</td>
<td>32</td>
</tr>
</tbody>
</table>

* Number of events indicates those events (potential vehicle/pedestrian conflicts) that were investigated, based on the vehicle’s entry into the intersection after the beginning of yellow phase.

Ø Data analyzed between 10:30 am to 5 pm.

Ø Typical Yellow duration = 3 secs, All-Red Phase=1.5 to 2 secs.
### Sample SMART Signal data

<table>
<thead>
<tr>
<th>Detector</th>
<th>Actuation start</th>
<th>occ (secs)</th>
<th>Phase</th>
<th>Signal start</th>
<th>status</th>
<th>dur (secs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>10:30:33.515</td>
<td>2.578</td>
<td>6</td>
<td>10:30:30.328</td>
<td>G</td>
<td>59.203</td>
</tr>
<tr>
<td>26</td>
<td>10:30:37.125</td>
<td>1.218</td>
<td>6</td>
<td>10:31:29.531</td>
<td>Y</td>
<td>5.5</td>
</tr>
<tr>
<td>26</td>
<td>10:30:39.281</td>
<td>0.969</td>
<td>6</td>
<td>10:32:23.828</td>
<td>G</td>
<td>55.703</td>
</tr>
<tr>
<td>26</td>
<td>10:30:42.921</td>
<td>0.813</td>
<td>6</td>
<td>10:33:19.531</td>
<td>Y</td>
<td>5.5</td>
</tr>
<tr>
<td>26</td>
<td>10:30:45.359</td>
<td>0.859</td>
<td>6</td>
<td>10:33:59.640</td>
<td>G</td>
<td>73.891</td>
</tr>
<tr>
<td>26</td>
<td>10:30:46.750</td>
<td>0.734</td>
<td>6</td>
<td>10:35:13.531</td>
<td>Y</td>
<td>5.5</td>
</tr>
<tr>
<td>26</td>
<td>10:31:01.156</td>
<td>0.422</td>
<td>6</td>
<td>10:36:25.031</td>
<td>G</td>
<td>72.5</td>
</tr>
<tr>
<td>26</td>
<td>10:31:02.859</td>
<td>0.375</td>
<td>6</td>
<td>10:37:37.531</td>
<td>Y</td>
<td>5.5</td>
</tr>
<tr>
<td>26</td>
<td>10:31:19.109</td>
<td>0.344</td>
<td>6</td>
<td>10:38:54.343</td>
<td>G</td>
<td>47.203</td>
</tr>
</tbody>
</table>
Typical Vehicle Pedestrian Collision
Assessing the effectiveness of Clearance Interval

- First assume no All-Red phase.
- Given initial estimates of vehicle’s position and speed (SMART Signal).
- Assume typical pedestrian behavior at signalized intersection.
- Verify two conflicting movements resulted in crash or not.
Schematic Diagram of Critical Event (CE)

Note: A CE happens if the car reaches the critical zone, with pedestrian still present within the zone.

\[ Y = \begin{cases} 1, & \text{if } t_1 \leq t_3 \leq t_2 \\ 0, & \text{otherwise.} \end{cases} \]

\[ t_3 = f(t_{\text{red}}, v_c) \]

\[ (t_1, t_2) = g(r_p, v_p) \]

\[ \Pr[CE \text{ occurs}] = \Pr(t_1 \leq t_3 \leq t_2) \]
Braking Model

Ø Allow for the fact driver can take evasive action, i.e. braking only.

Ø Collision can be avoided under three conditions.
Schematic Diagram for the Critical Set under Braking

Critical set

\[ \{d: d_v \leq d_{red} \leq d_{11}\} \cap \{t_1 \leq t_3 \leq t_2\} \]
# Simulation Parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Distribution</th>
<th>Mean</th>
<th>Std. Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driver Reaction Time</td>
<td>Log-Normal</td>
<td>1.07 sec</td>
<td>0.248 sec</td>
</tr>
<tr>
<td>Emergency braking</td>
<td>Log-Normal</td>
<td>0.63 g</td>
<td>.08 g</td>
</tr>
<tr>
<td>Pedestrian Speed</td>
<td>Uniform</td>
<td>4.25 feet/sec</td>
<td>0.907 feet/sec</td>
</tr>
<tr>
<td>Pedestrian Reaction</td>
<td>Uniform</td>
<td>0.85 sec</td>
<td>0.14 sec</td>
</tr>
</tbody>
</table>
Example: Reconstruction of CE

• Vehicle arrival after the onset of yellow.
• Initial speed of vehicle=42.63 feet/sec. (source: SMART signal)

• City Engineer’s dilemma:

Whether a Crash/CE would have occurred if ALL-RED was removed? If so, how severe it would be?
Reconstruction of CE

Vehicle trajectory and pedestrian location graph with vehicle speed estimated as 19.77 feet/second.
Assessing Effectiveness of All-Red Phase

• Probability of a CE being avoided by driver’s evasive action which would have occurred without all-red phase.

• Probability of a CE being avoided by introducing all-red phase, which would have occurred without all-red phase.

• Proportion of CE would be avoided by all-red phase which would not have been circumvented by driver’s evasive action.
Crash Reduction: Causal Inference

\[ z = \begin{cases} 
0, & \text{if control absent, i.e. initial condition.} \\
1, & \text{if present.} 
\end{cases} \]

\[ Y_{0j} = \begin{cases} 
0, & \text{if } CE_j \text{ does not occur when } z = 0 \\
1, & \text{if } CE_j \text{ occurs when } z = 0 
\end{cases} \]

\[ Y_{j,z=1} = \begin{cases} 
0, & \text{if } CE_j \text{ would not have happened when } z = 1 \\
1, & \text{if } CE_j \text{ would have occurred when } z = 1 
\end{cases} \]

\[ E[\Delta] = \sum_{\{j:Y_{0j}=1\}} E[Y_{0j} - Y_{j,z=1} \mid Y_{0j} = 1, z = 0] \]

\[ E[\Delta] = \sum_{\{j:Y_{0j} = 1\}} P[Y_{j,z=1} = 0 \mid Y_{0j} = 1, z = 0] \]
Probability of Necessity: CRF

\[ Z=00, \text{ if no braking and no All-red phase (AR)} \]
\[ =10, \text{ if braking and no AR} \]
\[ =01, \text{ if no braking and AR} \]

Now, let \( Y = Y_{00} \) if \( Z=00 \)
\[ = Y_{10} \] if \( Z=10 \)
\[ = Y_{01} \] if \( Z \)

\[ Y_{00} = 1, \text{ if } v_c \times t_1 \leq d_{red} \leq v_c \times t_2 \]
\[ = 0, \text{ otherwise} \]

\[ Y_{01} = 1, \text{ if } v_c \times t_1 \leq d^1_{red} \leq v_c \times t_2 \]
\[ = 0, \text{ otherwise} \]

where, \( d^1_{red} = d_{init} - v_c \times (ar + t_{red}) \),

\[ PN_b = \Pr(Y_{10}=0|Y=1, Z=00) \]
\[ PN_{ar} = \Pr(Y_{01}=0|Y=1, Z=00). \]
Note: Figure provided by Dr. Liu
Results

Boone Ave/TH 55

Comparing PN for braking and AR for site 1: (a) NB, (b) WB approach
Intersection Layouts (Contd’)

Note: Figure provided by Dr. Liu
Results

(a) Comparing PN for braking and AR for site 2: (a) SB (b) NB approach

Winnetka Ave/TH 55
Results

Comparing PN for braking and AR for site 3: EB approach.

Eden prairie TH 312/5 ramp
Conclusions

• Data from SMART-SIGNAL along with assumption on typical pedestrian behavior can provide an alternate estimate of vehicle/pedestrian crash reduction factor for clearance interval could be established.

• In almost all the cases, intervention of All-Red phase was sufficient to avoid CE/Crash, where braking would have failed.

• Why the discrepancy b/w our study and Retting’s results?
  - Relative proportion of subset of crashes with potential of being affected by clearance interval.
THANK YOU