Design and Field evaluation of the Dilemma Zone Protection System (DZPS) at US 40 & MD 910C

By Traffic Safety and Operations Lab
Location overview
Accidents history
Field data collection (pre-deployment)
Field implementation
  Key activities and issues
Field data collection (post-deployment)
Evaluation of Short-term impacts
  Speeds, acceleration/deceleration rates, decisions of drivers, distributions of dilemma zones
Performance evaluation
Summary of findings
Location Overview

- US 40 @ Western Maryland Parkway
  - 4-lanes divided highway (US 40), 3 approach lanes for Western Maryland Parkway (2-left, 1-right)
  - Isolated intersection
  - 55 mph speed limit
  - Ramp from I-81 for eastbound
  - 5% HV
Accident History

- Historical accidents data (2011 ~2013)
- 7 crashes potentially related to dilemma zone decisions for 3 years (side-angle crashes)
- 3 injuries
Field Data Collection (before deployment)

- 4 video camcorders with two reference points
  - 900 ft, 650ft, 500 ft, and 200ft
- 1 camcorder for the stop line and the signal

Data Collection Period
- Oct 10th 2014 from 11:30 AM to 12:30 PM and 3:00 PM to 6:00 PM

Data Processing
- Video times are synced with the GPS satellite time

900 ft video capture  signal video capture
Field Deployment of the system

- Two sensors on EB on US 40
  - EB sensor 1: Green Extension, All-red Extension
  - EB sensor 2: All-red Extension
- One sensor on WB on US 40
  - WB sensor 1: Green Extension
Key deployment Activities

- Check the sensor’s function
- Validate the speed and location of approaching vehicle with sensor data
- Checked whether or not the sensor sending proper calls to the signal controller
- Using camcorders to record and measure signal timings
- Identify if there are all-red extension calls from the recorded video
- Identify red-light running vehicles
- Compare all-red extensions and red-light running vehicles to identify missed calls, false alarm, and correct calls
DZPS Activated on Oct 13, 2016
Evaluation of the Short-Term impacts

- **Purposes:**
  - To evaluate the effectiveness of the system
  - Impacts on driver behaviors and traffic conditions
  - The performance of DZPS with respect to preventing side-crash accidents.

March 2014 accident on MD 213 and Locust Point Rd
Impacts by the roadside sensors?

- Impacts on the traffic?
- any change in the Speed?
- any change in acceleration/deceleration rates?
- any change on decisions of drivers during the yellow phase?

US 40 @ Red Toad road

US 40 @ MD 910C
Field Data Collection after deployment

- Signal timings
- Camcorders
- Traffic speeds and locations
- Sensors
- Six-day day for decisions of drivers during the yellow phase
- One day for system performance
Impacts on Traffic Flow Speed

- **Average speed reduced** at 900 feet and 200 feet
- **Not very significant reduction** at 500 feet

### Average Speed for different locations

<table>
<thead>
<tr>
<th>Location</th>
<th>900 feet</th>
<th>500 feet</th>
<th>200 feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Collection Period</td>
<td>Before</td>
<td>After</td>
<td>Before</td>
</tr>
<tr>
<td>Average speed (mph)</td>
<td>49.7</td>
<td>44.6</td>
<td>46.4</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>10.6</td>
<td>6.24</td>
<td>6.7</td>
</tr>
<tr>
<td>Minimum speed (mph)</td>
<td>18.9</td>
<td>23</td>
<td>10.9</td>
</tr>
<tr>
<td>Maximum speed (mph)</td>
<td>74.1</td>
<td>75</td>
<td>69.4</td>
</tr>
<tr>
<td>Sample Size</td>
<td>1233</td>
<td>2943</td>
<td>1371</td>
</tr>
</tbody>
</table>
Impacts on Traffic Flow Speed

- Percentage of the high-speed drivers (above speed limit at 900 feet) reduced from 29% to 16%.
- Vehicles slowdown when they approaching the intersection.

<table>
<thead>
<tr>
<th>Speed</th>
<th>Before Frequency</th>
<th>Before Percentage</th>
<th>After Frequency</th>
<th>After Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>75+</td>
<td>14</td>
<td>1%</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>70-75</td>
<td>36</td>
<td>3%</td>
<td>3</td>
<td>0%</td>
</tr>
<tr>
<td>65-70</td>
<td>58</td>
<td>5%</td>
<td>6</td>
<td>0%</td>
</tr>
<tr>
<td>60-65</td>
<td>92</td>
<td>7%</td>
<td>94</td>
<td>3%</td>
</tr>
<tr>
<td>55-60*</td>
<td>160</td>
<td>13%</td>
<td>375</td>
<td>13%</td>
</tr>
<tr>
<td>50-55</td>
<td>189</td>
<td>15%</td>
<td>850</td>
<td>29%</td>
</tr>
<tr>
<td>45-50</td>
<td>206</td>
<td>17%</td>
<td>951</td>
<td>32%</td>
</tr>
<tr>
<td>40-45</td>
<td>236</td>
<td>19%</td>
<td>432</td>
<td>15%</td>
</tr>
<tr>
<td>35-40</td>
<td>153</td>
<td>12%</td>
<td>166</td>
<td>6%</td>
</tr>
<tr>
<td>30-35</td>
<td>68</td>
<td>6%</td>
<td>56</td>
<td>2%</td>
</tr>
<tr>
<td>25-30</td>
<td>19</td>
<td>2%</td>
<td>10</td>
<td>0%</td>
</tr>
<tr>
<td>Over Speed Limit (total)</td>
<td>360 (1231)</td>
<td>29%</td>
<td>478 (2943)</td>
<td>16%</td>
</tr>
</tbody>
</table>

* Speed limit: 55 MPH
Distribution of the dilemma zones

- Deceleration rate
  - Before the deployment: $-7.28 \text{ ft/s}^2$
  - After the deployment: $-11.27 \text{ ft/s}^2$
- Maximum length of the DZ
  - Before the deployment: 960 feet
  - After the deployment: 670 feet
- Distributions of the DZ reduced
Drivers’ decisions during the yellow phase

- More drivers at moderate speeds choose “STOP” decisions (below or around speed limit)
- Not significant impact on high-speed drivers

<table>
<thead>
<tr>
<th>Speed of vehicle on set of yellow (sample size)</th>
<th>Location of vehicles from stop line onset of yellow</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 - 100 ft</td>
</tr>
<tr>
<td>Before</td>
<td>After</td>
</tr>
<tr>
<td>45 - 55 mph</td>
<td>100%</td>
</tr>
<tr>
<td>(78)</td>
<td>(24)</td>
</tr>
<tr>
<td>55+ mph</td>
<td>100%</td>
</tr>
<tr>
<td>(9)</td>
<td>(7)</td>
</tr>
</tbody>
</table>

*1: Field: percentage of drivers taking the “Pass” decision from the field observations
*2: the number in parenthesis denotes the sample size.
Safety evaluation with the total length of Dilemma zone

\[ x_{ds} = x_c - x_0 = \frac{v_0^2}{2a_2} - v_0 \tau + (w + L) - \frac{1}{2} a_1^* (\tau - \delta_1)^2 \]

where:
- \( x_c \) = the critical distance for a smooth stop under the maximum deceleration rate;
- \( x_0 \) = the critical distance for "intersection clearance" under the maximum acceleration rate;
- \( \tau \) = duration of the yellow interval;
- \( \delta_1 \) = reaction time - lag of the driver - vehicle complex;
- \( \delta_2 \) = decision - making time of a driver;
- \( v_0 \) = approach speed of vehicles;
- \( a_1 \) = average vehicle acceleration rate;
- \( a_1^* \) = maximum acceleration rate of the approaching vehicles;
- \( a_2 \) = average vehicle deceleration rate;
- \( a_2^* \) = maximum deceleration rate of the approaching vehicles;
- \( w \) = intersection width; and
- \( L \) = average vehicle length.

\[ DZ_L = \sum L_i \times \frac{vol_i}{Vol_{Total}} \]

- Total length of the dilemma zone weighted by volume in each speed bin

\( L_i \) is the length of the dilemma zone for \( i \)th speed bin
\( Vol_i \) is the number of the volume in the \( i \)th speed bin
\( Vol_{Total} \) is the total number of vehicle

- Before: 73 feet and After: 44 feet
- 40% reduction
## Performance Evaluation on Detection and Activation

<table>
<thead>
<tr>
<th>MOE</th>
<th>Simulation</th>
<th>Field Operation*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red-light-running rate (RLR / 100 cycle)</td>
<td>9.5</td>
<td>1.6**</td>
</tr>
<tr>
<td>Extension call rate (extension call / cycle)</td>
<td>30%</td>
<td>31.7%</td>
</tr>
<tr>
<td>Detection rate (protected RLR)</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>False alarm rate (false alarm / cycle)</td>
<td>21%</td>
<td>30.1%</td>
</tr>
</tbody>
</table>

* Based on the 6 hours field observations, total of 312 Cycles.

** Five red light running vehicles during the data collection.

- 5 vehicles ran on the red phase
- System Provides all-red extension to all
- 100% detection rate
- 30% false alarm rate
Summary of Findings

Deployed DPZS can:
- Reduce the average approaching vehicle speed
- Reduce the percentage of high-speed vehicles
- Encourage drivers to take the “stop” action during the yellow phase

High-Speed vehicles:
- Are more likely to be reduced
- Side-street vehicles are protected by all-red extensions