Safety Evaluation of Dilemma Zone Protection System (DZPS) at High Speed Rural Intersections in Maryland

Sung Yoon Park, Ph.D. (MDOT SHA)
Hyeonmi Kim, Ph.D. (Univ. of MD)
Minseok Kim, P.E. (MDOT SHA)
Contents

› Background
› Dilemma Zone Protection System (DZPS)
› Deployment of the DZPS in Maryland
› Before-and-after Crash Patterns
› Field Observation on Driving Behaviors
› Extension of the DZPS
› Summary of Findings
Majority of Intersection Crashes

Red Light Running Vehicles

Hard Breaking Vehicles

-OR-

53.6%

(Source: U.S. DOT, NHTSA.)


Source: http://crownheights.info/accidents/page/4/
Dilemma Zone

- Potential contributors to Dilemma Zone related collisions
  - Insufficient duration of the yellow phase
  - Aggressiveness of drivers
    - High speed
  - Short sight distance
  - Driver’s characteristics
    - PRT, age, gender
  - Deceleration rate of vehicles
How to Prevent Crashes?

- Design
- Education (Campaign)
- Enforcement

Red Light Photo Enforced
Dilemma Zone Protection System (DZPS) System Configuration

- Key components:
  1. Wide-range sensor
  2. In-cabinet computer
  3. Controller
  4. Communication hardware
DZPS Control Strategy
All-Red Extension

Give an additional clearance time to red-light running vehicle to prevent angled crash

Vehicles on the main street are trapped in dilemma zones
Vehicles decide to run over the red

Dilemma Zone
Detection Zone of Long-range Microwave Detector(s)

Extend All-Red Phase
DZPS Deployment in Maryland
High speed rural intersections

Site 1) US 40 @ Red Toad Rd.
• DZPS in EB and WB approaches along US 40
• Posted speed limit: 55mph

Site 2) MD 213 @ Locus Point Rd
• DZPS in NB and SB approaches along MD 213
• Posted speed limit: 55mph

Site 3) US 40 @ Western Maryland Pkwy
• DZPS in EB approach along US 40
• T intersection
• Posted speed limit: 55mph
Before-and-after crash patterns
Site 1) US 40 at Red Toad Rd. (EB)

- EB DZPS **Deployed** in 2010
- EB DZPS **Adjusted** in 2016

**Before-and-after angled crashes**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Average Frequency</td>
<td>1.00</td>
<td>1.00</td>
<td>0.67</td>
</tr>
<tr>
<td>% EB Angled crashes</td>
<td>17.9%</td>
<td>16.7%</td>
<td>14.3%</td>
</tr>
</tbody>
</table>

**[EB Angled Crash Frequency]**

*without drug/alcohol related crash*
Before-and-after crash patterns
Site 1) US 40 at Red Toad Rd. (WB)

- WB DZPS Deployed in 2016

Before-and-after angled crashes

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Average Frequency</td>
<td>1.60</td>
<td>2.40</td>
<td>0.67</td>
</tr>
<tr>
<td>% WB Angled crashes</td>
<td>28.6%</td>
<td>40.0%</td>
<td>14.3%</td>
</tr>
</tbody>
</table>

Before-and-after crash patterns

- 18 month after DZPS deployment

Caused by a red-light running vehicle from the side street w/o DZPS
Before-and-after crash patterns
Site 1) US 40 at Red Toad Rd.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Average Frequency</td>
<td>2.60</td>
<td>3.40</td>
<td>1.33</td>
</tr>
<tr>
<td>% Angled crashes</td>
<td>46%</td>
<td>57%</td>
<td>29%</td>
</tr>
</tbody>
</table>

*without drug/alcohol related crash

[Total Crash Frequency]

After period: 18 month
Before-and-after crash patterns
Site 2) MD 213 at Locust Point Rd.

- NB and SB DZPS Deployed in 2016

**Before-and-after angled crashes**

<table>
<thead>
<tr>
<th>Angled Crash</th>
<th>2010-2015</th>
<th>2017-2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Average Frequency</td>
<td>1.67</td>
<td>0.67</td>
</tr>
<tr>
<td>% Angled crashes</td>
<td>62.5%</td>
<td>25.0%</td>
</tr>
</tbody>
</table>

After period: 18 month

---

**Angled Crash Frequency**

- 2010-2015: 1.67
- 2017-2018: 0.67
- % Angled crashes: 62.5% to 25.0%

**Total Crash Frequency**

- 2010-2015: 1.67
- 2017-2018: 0.67

*without drug/alcohol related crash
**one fatality crash: angled crash between SB Thru, WB Thru.
Before-and-after crash patterns

Site 3) US 40 at MD 910 C

- EB DZPS Deployed in 2016

Before-and-after angled crashes

<table>
<thead>
<tr>
<th></th>
<th>2010-2015</th>
<th>2017-2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Average Frequency</td>
<td>1.33</td>
<td>1.33</td>
</tr>
<tr>
<td>% Angled crashes</td>
<td>36.4%</td>
<td>100%</td>
</tr>
</tbody>
</table>

After period: 18 month

* without drug/alcohol related crash
Field Observation on Driving Behavior
Cumulative distribution of approaching speeds and detection rate

Field Observation on distribution of speeds and detection rates

<table>
<thead>
<tr>
<th>Speed (mph)</th>
<th>MD 213 (Site 2) Before</th>
<th>MD 213 (Site 2) After</th>
<th>US 40 (Site 3) Before</th>
<th>US 40 (Site 3) After</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency (%)</td>
<td>Frequency (%)</td>
<td>Frequency (%)</td>
<td>Frequency (%)</td>
</tr>
<tr>
<td>75+</td>
<td>N/A</td>
<td>14</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>70-75</td>
<td>3</td>
<td>36</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>65-70</td>
<td>3</td>
<td>92</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>60-65</td>
<td>8</td>
<td>94</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>55-60*</td>
<td>37</td>
<td>160</td>
<td>37</td>
<td>37</td>
</tr>
<tr>
<td>50-55</td>
<td>113</td>
<td>189</td>
<td>32</td>
<td>5</td>
</tr>
<tr>
<td>45-50</td>
<td>177</td>
<td>206</td>
<td>115</td>
<td>17%</td>
</tr>
<tr>
<td>40-45</td>
<td>147</td>
<td>236</td>
<td>254</td>
<td>38%</td>
</tr>
<tr>
<td>35-40</td>
<td>69</td>
<td>153</td>
<td>182</td>
<td>27%</td>
</tr>
<tr>
<td>30-35</td>
<td>58</td>
<td>87</td>
<td>77</td>
<td>12%</td>
</tr>
<tr>
<td>Over the Speed Limit (total)</td>
<td>51 (615)</td>
<td>360 (1231)</td>
<td>360 (1231)</td>
<td>29%</td>
</tr>
</tbody>
</table>

* Speed limit for US 40 and MD 213

- System detects all red-light running vehicles and provides all-red extension

Field Observation on Driving Behavior
Distribution of dilemma zone


MD 213 at Locust Point Rd. (Site 2)

US 40 at MD 910C (Site 3)
Field Observation on Driving Behavior
Drivers taking the ‘pass’ decision during the yellow

Potential Extension of the DZPS

Key components:
1. Wide-range sensor
2. In-cabinet computer
3. Controller
4. Communication hardware
Potential Extension of the DZPS

› Before the green phase becomes max-out
  – Find the safest time to terminate green for minimizing the number of vehicles trapped in the DZ

At max-out both vehicles trapped in the dilemma zone

At max-out one vehicle trapped in the dilemma zone
Potential Extension of the DZPS

- **Reduce** both angled and rear-ended crashes

- Slow down approaching traffic
- Less likely to be trapped in Dilemma Zones
- Stop safely at the intersection

Dilemma Zone

Detection Zone for Long-range Microwave Detector(s)

Activate the advisory speed sign
DZPS Deployment in Maryland

Under consideration for deploying DZPS with all-red extension and dynamic green termination

- US 301 @ Governor Bridge Rd.
- US 301 @ Billingsley Rd.
- MD 4 @ Forestville Rd.

DZPS deployed with all-red extension

Under consideration for deploying DZPS with all-red extension and dynamic green extension
Summary of Findings

› Deployed DZPS can
  – Identify all red-light running vehicles and provide all-red extensions.
  – Reduce the annual average number of angle crashes.
  – Decrease overall total number of crashes.

› Deployed DZPS has potential to
  – Reduce the percentage of high-speed vehicles.
  – Reduce the range of dilemma zones.
  – Encourage drivers to take the “STOP” action during the yellow phase.
THANK YOU

Sung Yoon Park, Ph.D.
spark@mdot.maryland.gov