Implementation of Low-Cost Countermeasures for Un-signalized Intersections Using Systemic Approach

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Background

- Every year, approximately 25% and 40% of fatal and injury crashes are occurred at intersections in the commonwealth of Virginia.

- Among these, over 50% of fatal and serious injuries are annual occurred at **Un-signalized (Stop sign control) intersections**.

- To achieve the vision for TZD (Toward Zero Deaths) in Virginia, reducing fatalities and serious injuries at the un-signalized intersections are inevitable.
Un-signalized Intersection

- Typical characteristics and circumstance are:
  1) Low volume and local roadway system
  2) Vast majority and widely distributed
  3) Lower crash density
  4) Low-cost countermeasures are affordable

- The site-specific approach “hot-spot approach” has limitations in developing comprehensive safety improvement projects for widely distributed un-signalized intersections in State and local roadway system.

Therefore, Systemic approach is needed for Improving safety at un-signalized Intersection!!
Systemic Approach (SA)

- **Definition:**
  Systemic approach is a comprehensive network screening method to develop a safety project by identifying specific roadway features that correlate with identified target collision types through a data-driven process using crash and roadway network data.

- **Benefits:**
  - Implement low-cost countermeasures
  - Return high cost-effectiveness
  - Applicable for both Pro- and Post-active improvement

- So, Map-21 encourages each State to consider/develop systemic safety improvements for the Strategic Highway Safety Plan (SHSP)
FHWA Recommended SA Process

1. Identify Focus Crash Types and Risk Factors
2. Screen and Prioritize Candidate Locations
3. Select Countermeasures
4. Prioritize Projects
Data

- 2011 – 2015 crash data were collected from VDOT crash dB (RNS-Crash)
- Un-signalized intersection roadway features such as highway system, area, cross-section, geometry, volume, etc. were collected from VDOT roadway inventory dB (RNS-RIM)
- 68,691 crashes and 25,420 un-signalized intersections (3-Leg: 21,753 and 4-Leg: 3,667) were collected for analysis.
Data Driven & Analysis Process in VA

S1: Identify Target Collision
- Rear-end
- Angle
- Head-on
- Sideswipe – SD
- Sideswipe – OD
- Fixed Object Off Road (FOOR)
- Deer or animal
- etc..

S2: Look for Features
- Area
- Approach lane combination
- Median type
- Highway system
- Functional class
- Entering AADT
- AADT ratio

S3: Assess Risk Level
- PSI (0)
- PSI (1)
- PSI (2)
- PSI (3)
- PSI (4)
- PSI (5)

S3: Develop Range and Scope
- Tier 1
- Tier 2
- Tier 3

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### Collision Type Distribution

<table>
<thead>
<tr>
<th>Collision Types</th>
<th># of Crash</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angle</td>
<td>22,109</td>
<td>32.2</td>
</tr>
<tr>
<td>Fixed Object Off Road (FOOR)</td>
<td>16,068</td>
<td>23.4</td>
</tr>
<tr>
<td>Rear-end</td>
<td>14,732</td>
<td>21.4</td>
</tr>
<tr>
<td>Deer or animal</td>
<td>3,956</td>
<td>5.8</td>
</tr>
<tr>
<td>Sideswipe - SD</td>
<td>2,730</td>
<td>4.0</td>
</tr>
<tr>
<td>Total</td>
<td>68,691</td>
<td>100.0</td>
</tr>
</tbody>
</table>

### Collision Types

<table>
<thead>
<tr>
<th>Collision Types</th>
<th># of Crash</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angle</td>
<td>15,491</td>
<td>27.9</td>
</tr>
<tr>
<td>Fixed Object Off Road (FOOR)</td>
<td>14,209</td>
<td>25.6</td>
</tr>
<tr>
<td>Rear-end</td>
<td>12,582</td>
<td>22.7</td>
</tr>
<tr>
<td>Deer or animal</td>
<td>3,399</td>
<td>6.1</td>
</tr>
<tr>
<td>Sideswipe - SD</td>
<td>2,221</td>
<td>4.0</td>
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<tr>
<td>Total</td>
<td>55,496</td>
<td>100.0</td>
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</table>

### Collision Types

<table>
<thead>
<tr>
<th>Collision Types</th>
<th># of Crash</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angle</td>
<td>6,618</td>
<td>50.2</td>
</tr>
<tr>
<td>Rear-end</td>
<td>2,150</td>
<td>16.3</td>
</tr>
<tr>
<td>Fixed Object Off Road (FOOR)</td>
<td>1,859</td>
<td>14.1</td>
</tr>
<tr>
<td>Deer or animal</td>
<td>557</td>
<td>4.2</td>
</tr>
<tr>
<td>Sideswipe - SD</td>
<td>509</td>
<td>3.9</td>
</tr>
<tr>
<td>Total</td>
<td>13,195</td>
<td>100.0</td>
</tr>
</tbody>
</table>

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Look for Features

METHOD

- **CHAID (Chi-Square Automatic Interaction Detection) Decision Tree Analysis** was applied to identify features of un-signalized intersections where target collision is occurred more often.

  - Conduct automatic ransacking processes such as splitting, merging and stopping dataset to identify key relationships.
  - Pearson chi-squared statistic is used to estimate.

\[
X^2 = \sum_{j=1}^{J} \sum_{i=1}^{I} \frac{(n_{ij} - \hat{m}_{ij})^2}{\hat{m}_{ij}}
\]
Ex: CHAID Tree in Medical

- Patients: 200
- HBP: 50
- Attributes Features:
  a. Family History
  b. Gender
  c. Age
  d. Smoke
  e. Alcohol

Who are the highest HBP group?

Answer: Both with HBP &
Age > 60 &
Alcohol > 5

High Risk Value: 2.44 (= 0.61/0.25)
- Identified a group of high risk HBP is
  - Both parents have HBP &
  - Age > 60 &
  - Alcohol consumption > 5 (per week)

![Diagram showing treatment levels: High, Medium, Low]
Intersection Features

3-Leg (21,753)
1. Angle (15,491)
2. FOOR (14,209)
- INT₃ (Angle) > 22.5%
- INT₃ (FOOR) > 33.1%

4-Leg (3,667)
1. Angle (6,618)
2. Rear-end (2,150)
- INT₄ (Angle) > 43.7%
- INT₄ (Rear-end) > 13.7%
# Intersection Feature Detail

<table>
<thead>
<tr>
<th>Area</th>
<th>Highway System</th>
<th>Approach Lane</th>
<th>Median Type</th>
<th>Functional Class</th>
<th>Entering AADT</th>
<th>AADT Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban, Rural</td>
<td>Prim – Prim</td>
<td>2 – 2</td>
<td>Undiv – Undiv</td>
<td>Prim Art – PrimArt</td>
<td>&lt;= 5,000</td>
<td>50% – 50%</td>
</tr>
<tr>
<td></td>
<td>Prim – Sec</td>
<td>4 – 2</td>
<td>Div – Undiv</td>
<td>Prim Art – MinArt</td>
<td>5,001 – 10,000</td>
<td>60% – 40%</td>
</tr>
<tr>
<td></td>
<td>Sec – Sec</td>
<td>4 – 4</td>
<td>Div – Div</td>
<td>Prim Art – Col</td>
<td>10,001 – 15,000</td>
<td>70% – 30%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Min Art – MinArt</td>
<td>15,001 – 20,000</td>
<td>80% – 20%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Min Art – Col</td>
<td>20,001 – 25,000</td>
<td>90% – 10%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Min Art – Loc</td>
<td>25,001 – 30,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Col – Col</td>
<td>30,001 – 35,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Col – Loc</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Loc – Loc</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
CHAID Tree: 3-Leg, Angle

AADT > 15001

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CHAID Tree: 3-Leg, FOOR

AADT <= 5000

Rural
CHAID Tree: 4-Leg, Angle

ANTGLE_PCENT_43.7
Node 0
Category % n
- No 49.3 1000
- Yes 50.7 1858
Total 100.0 2858

INT APPROACH AADT RATIO?
Adj. P-value=0.030, Chi-square=99, df=1

50:50, 60:40, 70:30, 80:20

Node 8
Category % n
- No 31.4 153
- Yes 68.6 335
Total 100.0 488

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CHAID Tree: 4-Leg, Rear-end

AADT > 10,000
Urban

RE_PCNENT_137

Node 0
Category % n
No 26.0 1027
Yes 72.0 2840
Total 100.0 3867

INT ENTERING VOLUME
Adj. P-value=0.000, Chi-square=575.578, df=2

Urban

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## Screening Results

<table>
<thead>
<tr>
<th>Intersection Type</th>
<th>Target Collision</th>
<th>Identified Features</th>
<th># of Selected Intersection</th>
</tr>
</thead>
</table>
| 3-Leg (21,753)    | Angle            | ▪ AADT > 15,000  
▪ Functional Class  
  - Prim Art – Col  
  - Min Art – Min Art  
  - Min Art – Col  
  - Loc – Loc         | 197                          |
|                   | FOOR             | ▪ Rural  
▪ AADT <= 5,000  
▪ Highway System  
  - Prim – Prim  
  - Sec – Sec     | 4,094                        |

<table>
<thead>
<tr>
<th>Intersection Type</th>
<th>Target Collision</th>
<th>Identified Features</th>
<th># of Selected Intersection</th>
</tr>
</thead>
</table>
| 4-Leg (3,667)     | Angle            | ▪ AADT > 5,000  
▪ AADT Ratio  
  - 50% – 50%  
  - 60% – 40%  
  - 70% – 30%  
  - 80% – 20% | 335                          |
|                   | Rear-end         | ▪ Urban  
▪ AADT > 10,000  
▪ Median Type  
  - Undiv – Undiv | 172                          |
Identified un-signalized intersections for each target collisions are divided into risk levels using annual PSIs over five year period.

<table>
<thead>
<tr>
<th>PSI &gt; 0</th>
<th>Angle @ 3-Leg</th>
<th>FOOR @ 3-Leg</th>
<th>Angle @ 4-Leg</th>
<th>Rear-end @ 4-Leg</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSI (5 yr)</td>
<td>17</td>
<td>13</td>
<td>26</td>
<td>1</td>
<td>57</td>
</tr>
<tr>
<td>PSI (4 yr)</td>
<td>28</td>
<td>63</td>
<td>31</td>
<td>16</td>
<td>138</td>
</tr>
<tr>
<td>PSI (3 yr)</td>
<td>40</td>
<td>261</td>
<td>57</td>
<td>21</td>
<td>379</td>
</tr>
<tr>
<td>PSI (2 yr)</td>
<td>40</td>
<td>969</td>
<td>62</td>
<td>40</td>
<td>1,111</td>
</tr>
<tr>
<td>PSI (1 yr)</td>
<td>37</td>
<td>2,748</td>
<td>74</td>
<td>53</td>
<td>2,912</td>
</tr>
<tr>
<td>PSI (0 yr)</td>
<td>35</td>
<td>40</td>
<td>85</td>
<td>41</td>
<td>201</td>
</tr>
<tr>
<td>Total</td>
<td>197</td>
<td>4,094</td>
<td>335</td>
<td>172</td>
<td>4,798</td>
</tr>
</tbody>
</table>
S4 Project Scope and Range

- Low-Cost Countermeasures Implemented into 3 Tiers as
# Project Scope and Range

## Table: PSI > 0

<table>
<thead>
<tr>
<th>PSI &gt; 0</th>
<th>Angle @ 3-Leg</th>
<th>FOOR @ 3-Leg</th>
<th>Angle @ 4-Leg</th>
<th>Rear-end @ 4-Leg</th>
<th>Total</th>
</tr>
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<tr>
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<td>41</td>
<td>201</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>197</td>
<td>4,094</td>
<td>335</td>
<td>172</td>
<td>4,798</td>
</tr>
</tbody>
</table>

## Diagrams: Tier 1, Tier 2, Tier 3

## Table: Scope

<table>
<thead>
<tr>
<th>Tier</th>
<th>Scope A</th>
<th>Scope B</th>
<th>Scope C</th>
<th>Scope D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tier 1</td>
<td>$141,000</td>
<td>$464,000</td>
<td>$1,300,000</td>
<td>$3,624,000</td>
</tr>
<tr>
<td>Tier 2</td>
<td>$211,500</td>
<td>$696,000</td>
<td>$1,950,000</td>
<td>$5,436,000</td>
</tr>
<tr>
<td>Tier 3</td>
<td>$394,500</td>
<td>$1,294,500</td>
<td>$3,613,000</td>
<td>$10,029,500</td>
</tr>
</tbody>
</table>

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Results: SA with CHAID Tree

Overall, Improvement is 2.2 times
Conclusions

- VDOT has successfully developed systemic safety improvement plan using a data-driven approach for un-signalized intersections.
- The CHAID tree analysis is very effective in finding the characteristics of intersection where the target collisions are highly concentrated.
- To achieve a goal of TZD, the systemic safety improvement plan for un-signalized intersections will implement in the FY19 Highway Safety Improvement Program (HSIP)
- The low-cost treatments in a tree-tier approach enable the treatment of more intersections in a comprehensive manner.
Thank You!!