Evaluation of Advance Warning at High Speed Rural Intersections

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Outline

• Background
• Motivation for Research
• Research Method
• Results
• Conclusion and Recommendations
Background

Dilemma or Indecision Zone

• Signalized intersections are locations with a high crash potential
• Because of a region known as “Dilemma Zone” or “Indecision Zone”
Background

Dilemma or Indecision Zone

Dez = Distance to the end of the indecision zone
Dtz = Distance to the beginning of the indecision zone
Background

Dilemma or Indecision Zone

• Whereas, in theory, this zone does not exist
  – Because the yellow interval is timed to eliminate this...

• Driver behavior and vehicle characteristics are stochastic!!

• Particularly at isolated signalized rural intersections
  – Higher speeds, and
  – Heavy truck volumes

• A commonly adopted countermeasure is Advance Warning Systems (AWS)

• ODOT was one of the pioneer institutions to use AWS that are now widely used across the country
Background

Advance Warning Systems

• Typical AWS
  – W3-3 sign
  – Flashing beacons
  – Delay call loops

• Typical amber warning interval is based on 85th percentile speed

• Location of sign is determined based on timing, 85th percentile speed, and approach grade
Background

Advance Warning Systems with Advance Detection

Advance Detectors
Background

Effectiveness of AWS and/or Advance Detection

• Literature indicates:
  – Can reduce left turn, right angle, and rear end crashes (Gaziz, 1996)
  – Found to be more effective at locations with minor street volumes of 13,000 or greater AADT (Sayed, 1999)
  – Found to reduce red-light running by 29% and 63% for trucks (Farraher, 1999)
  – AWS combined with advance detection (Advance Warning for End of Green System) reduced red light running by 38% (Messer, 2004)
  – Found that the system increases safety but also increases risky behavior (Farraher, 1999)
Motivation for Research

Effectiveness of AWS and/or Advance Detection

- Previous research shows how AWS improve safety
- Recently they have been known to lead risky driver behavior
- ODOT has begun removing some of these systems and replacing with ITS system
- Truck volumes have been increasing and raise concern for safety
- Operational evaluation of driver behavior
Background

ITS Technology

• Continuous Vehicle Tracking
  – Tracks vehicles speed and displacement
  – System uses an algorithm to reduce dilemma zone
  – Can provide priority to certain vehicle classifications

• No advance warning signal for the driver
Background

Sensor Location

US-33 & Pickerington Rd.
Safety Assessment

- Before after study comparing treatment sites to control sites

<table>
<thead>
<tr>
<th>Technique</th>
<th>Controlling Factors</th>
<th>Data Requirements</th>
<th>Complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Exposure</td>
<td>Long Term</td>
<td>Regression to the mean</td>
</tr>
<tr>
<td>Naïve Before and After</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Low (Crash History)</td>
<td>Low (Spreadsheet)</td>
<td></td>
</tr>
<tr>
<td>Empirical Bayes Methodology</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>High (Crash History, Traffic Volumes, Geometry)</td>
<td>Medium (Statistical Software)</td>
<td></td>
</tr>
<tr>
<td>Full Bayes Methodology</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Medium (Crash History, Traffic Volumes)</td>
<td>High (Statistical Software, Computational Software)</td>
<td></td>
</tr>
</tbody>
</table>
Safety Assessment

- Naive
  - Total
  - PDO
  - Injury
  - Fatal
  - Rear-End
  - Angle
  - Truck

- Empirical Bayes
  - Total
  - PDO
  - Injury
  - Fatal
  - Rear-End
  - Angle
  - Truck

- Full Bayes
  - Total
  - PDO
  - Injury
  - Fatal
  - Rear-End
  - Angle
  - Truck
Data

Intersection Selection Criteria

• Must be signalized
• With high speed approaches
  – Speed of 45mph or greater
• Four approaches
• Rural location
• Previous use of AWS
Data
Selected sites

30 Sites were selected for analysis
• 12 treatment sites
• 18 control sites
Data

Specific from selected sites

Crash Data

• Analysis period from 2010-2016
• Data was pulled from ODOT GIS Crash Analysis Tool (GCAT)
• Crashes area selected was based on size of dilemma zone, which varied depending on speed limit of roadway

Traffic Volumes

• The corresponding traffic volumes were pulled from ODOT’s Transportation Data Management System
Crash History At-A-Glance

Treatment Site

Control Site

SHARP RD.
US-33
SR-32
SR-41
SR-32
US-33
SR-41
Crash History At-A-Glance

BEFORE PERIOD

2010 2011 2012
8 7 5

TREATMENT PERIOD

2013 2014 2015
14 11 9 11 9

Control Site  Treatment Site
Naïve before-after analysis

Method

• Simple comparison of observed data from before and after treatment periods.
Naïve before-after analysis

Method

• Looked at crash rates by type
• Compared the before rate with the after to measure the change
• Gives an overall idea of what the trend was
• To evaluate differences a chi-square test was used
• Chi-square is a statistical method for assessing the fit between observed values
Naïve before-after analysis

Results

• Overall there was no significant difference between crash rates at treatment site versus control sites

• Further analysis of treatment showed:
  – Fatal crash rates were reduced by 0.3/yr.
  – Rear-end crash rates were reduced by 1.0/yr.
  – Truck crash rates were increased by 0.44/yr at treatment sites, but when compared to control sites the number of crashes increased by 0.1/yr
Naïve before-after analysis

Method

• However, issues with Naive method
• Regression-to-the-mean is a concern
• Changes in safety reflect changes in all types of factors such as traffic, weather, and driver behavior
• Changes can be in response to regression-to-the-mean instead of treatment
• So, there could be exaggerated effects of the treatment!!
Empirical Bayes Analysis

Method

Highway Safety Manual (HSM) 2010
- Predictive method for estimating crash frequency and severity
- Used for planning, design, operations, and maintenance
- Catalog of crash modification factors for geometric and operational treatments
- Three main facility types
  - Rural tow-lane roads
  - Rural multilane highways
  - Urban and suburban arterials

- Structured methodology to estimate expected average crash frequency
- Utilizes historical data to create base model
- \( N_{\text{predicted}} = N_{\text{spf}} \times C_i \times \text{CMF}_{1,2,3,4} \)
- Crash modification factors (CMF’s) account for deviations from base model
- Removes the effect of regression to the mean
Empirical Bayes Analysis

Base Model

• Base model for rural multilane highway 4-leg intersections from the Highway Capacity Manual

\[ N_{SPF} = e^{[-10.008 + 0.848 \ln(AADT_{maj}) + 0.448 \ln(AADT_{min})]} \]
Empirical Bayes
Crash Modification Factors

<table>
<thead>
<tr>
<th>Type</th>
<th>Advance Warning</th>
<th>Smart Sensor</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Crashes</td>
<td>0.918</td>
<td>1.190</td>
</tr>
<tr>
<td>Injury/Fatal</td>
<td>0.887</td>
<td>0.530</td>
</tr>
<tr>
<td>Rear End</td>
<td>0.988</td>
<td>0.706</td>
</tr>
<tr>
<td>Angle Crashes</td>
<td>0.564</td>
<td>0.484</td>
</tr>
<tr>
<td>Truck Related</td>
<td>0.995</td>
<td>0.127</td>
</tr>
</tbody>
</table>

- AWS CMF’s were currently available
- CMF’s for the smart sensor were created based on crash history for this study using the method from FHWA
Empirical Bayes Analysis

Results

• Looking at the total crashes results indicated an increase of 1.7 crashes per year at treatment sites compared to the control sites.

• Further analysis of treatment showed:
  – Rear-end crash rate decreased by 0.9/yr
  – Other crash types were not found to have a significant change.
Full Bayesian Method

- Widely accepted method by researchers
- Similarly to EB this approach uses prior and current information
- Requires less data
- Accounts for uncertainty in data used
- Provides for detailed inferences
- Mitigates the effect of regression to the mean
## Comparison of Results

<table>
<thead>
<tr>
<th>Method</th>
<th>Naive</th>
<th>Empirical Bayes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Crashes</strong></td>
<td>Not Significant</td>
<td>Increase 1.7/yr</td>
</tr>
<tr>
<td><strong>Property Damage Only</strong></td>
<td>Not Significant</td>
<td>Not Significant</td>
</tr>
<tr>
<td><strong>Injury</strong></td>
<td>Not Significant</td>
<td>Not Significant</td>
</tr>
<tr>
<td><strong>Fatal</strong></td>
<td>Decrease 0.3/yr</td>
<td>Not Significant</td>
</tr>
<tr>
<td><strong>Rear-End</strong></td>
<td>Decrease 1.0/yr</td>
<td>Decrease 0.9/yr</td>
</tr>
<tr>
<td><strong>Angle</strong></td>
<td>Not Significant</td>
<td>Not Significant</td>
</tr>
<tr>
<td><strong>Truck</strong></td>
<td>Increase 0.1/yr</td>
<td>Not Significant</td>
</tr>
</tbody>
</table>
Conclusion & Recommendations

• The ITS device is effective at reducing rear-end crashes
• The device is also has some effect on reducing the severity of crashes
• There was a significant increase in truck crashes at the treatment sites
On-Going Research

• Full Bayesian analysis
• Operational data is being collected to determine driver behavior at control intersections versus the treatment sites
  – Looking at driver speeds
  – Determining acceleration/deceleration
  – Identifying risky behavior and likelihood of occurrence
Questions