EFFECTS OF PAVEMENT WIDENING AND RUMBLE STRIPS ON TWO-LANE RURAL HIGHWAYS

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Outline

- Introduction
- Methodology
- Results and discussion
- Conclusions
- Recommendations
Crashes are rare and random events

Roadway departure crashes (run-off-road)
- National level (2011): 16,948 fatalities – 51% of fatal crashes (FHWA, 2013)
- State level (2010): 458 fatalities – 25% of all reported crashes, 42% of incapacitating injuries, 53% of fatalities (ALDOT, 2012)

Rural roads
- 27% of all crashes in Alabama
- 62% of fatal crashes
Background

- Alabama Department of Transportation (ALDOT) policy – 2006
  - Widen pavements and install milled-in rumble strips when rural two-lane highways with less than 28 ft of pavement width are resurfaced
  - Shoulders: 2 ft of full-depth pavement added on each side of the roadway
  - In some cases, rumble strips or stripes were scored into the pavement within the 2 ft shoulder
Motivation

- Level of investment associated with this policy
- Safety benefits
- Study to quantify the potential benefits was needed
Objectives

- Estimate reduction in crash severity using Equivalent Property Damage Only (EPDO) scores
- Develop crash modification factors (CMF) applying the Empirical-Bayes (EB) method, as outlined in the *Highway Safety Manual* (AASHTO, 2010)
- Quantify the benefits and costs of the ALDOT policy based on the National Highway Traffic Safety Administration (NHTSA) report (Blincoe et al., 2014)
- Make recommendations for future application
Run-off-road (ROR) crashes

- Roadway departure event
- Single-vehicle crash
- Vehicle leaves the travel lane and strikes one or more of any number of natural or artificial objects

Factors:
- Driver inattention
- Driver fatigue
- Roadway surface conditions
- Alcohol presence
- Driver’s familiarity with the roadway

Source: Marion County, 2012
Countermeasures: safety effectiveness

- Paved shoulders, shoulder rumble strips, shoulder rumble stripes

- How to measure safety effectiveness?
  - How safety was in the period “before” the treatment was implemented, and how it changed at the “after” period, has the treatment been implemented
  - Model crashes
    - Fluctuations over time
    - Regression-to-the-mean (RTM) bias
  - Methods
    - Crash rates
    - Indirect or surrogate safety measures for identifying high crash locations
    - Statistical analysis
- Crash fluctuation  
  (Source: AASHTO, 2010)

- RTM bias  
  (Source: AASHTO, 2010)
Safety effectiveness methods: evolution

- Naïve before-after
  - Count of “before” period crashes can be used to predict what would have been the expected count of “after” period crashes

- Comparison group
  - The treated sites are the “treatment group”, and the untreated sites are the “comparison group”
  - The change from “before” to “after” in the safety of the comparison group is indicative of how safety on the treatment group would have changed

- Empirical-Bayes (EB)
  - Increases the precision of estimates when there are no long-term data available
  - No regression-to-the mean bias
Shoulder rumble strips and stripes

- Rumble strips
  (Source: Baxter, 2004)

- Rumble stripes
  (Source: MnDOT, 2012)
## Existing Crash Modification Factors (CMFs)

<table>
<thead>
<tr>
<th>HSM CMFs</th>
<th>CMF Clearinghouse</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ Shoulder width</td>
<td>□ Complete study developed by Torbic at al., in 2009 – NCHRP Report 641</td>
</tr>
<tr>
<td>▪ Base condition: 6 ft</td>
<td>□ CMFs for adding rumble strips and stripes, but shoulder width generalized as &lt;5 ft</td>
</tr>
<tr>
<td>▪ Not specific to ROR crashes</td>
<td>□ No CMFs for the combined effect (paved shoulder and scoring)</td>
</tr>
<tr>
<td>□ Rumble strips</td>
<td></td>
</tr>
<tr>
<td>▪ No CMFs for rumble strips or stripes on two-lane rural roads</td>
<td></td>
</tr>
</tbody>
</table>
Methodology

- Data Collection
  - Field data verification: assisted by several personnel of the ALDOT Office of Safety Operations
  - 83 sites in the state of Alabama
  - Two-lane rural roads
  - Shoulder width in a range from 2 to 4 ft
  - Three treatments
    - Pavement widening without scoring
    - With rumble strips
    - With rumble stripes
Methodology

- Of the two-lane rural roads
  - 40 sites had rumble strips
  - 12 had rumble stripes
  - 31 had only the shoulder paved
- Crash data: Critical Analysis Reporting Environment (CARE)
- Traffic data (AADT): ALDOT
- Cost data: ALDOT, Tabulation of Bids
Methodology

- Data analysis
  - 3 years of data before
  - 3 years of data after
  - EB method in the HSM
  - EPDO scores
  - Benefit/cost analysis
Empirical-Bayes (EB) method: HSM

- Uses a Safety Performance Function (SPF)
- Weights the observed crash frequency with the SPF-predicted average crash frequency
- Obtains an expected crash frequency
- At least 10 to 20 sites
- 3 to 5 years of crash and traffic volume data for the periods before and after treatment implementation

Source: FHWA, 2010
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Source: FHWA, 2010
EPDO Analysis

- Equivalent property damage only (EPDO) method
- Extension of the Naïve before-after analysis
- Data needed:
  - Crash frequency by severity
  - Crash weighting factors by severity
- Each crash is weighted based on the crash severity and the equivalent property damage only crash cost

<table>
<thead>
<tr>
<th>Crash Severity</th>
<th>Comprehensive Costs (Dollars)</th>
<th>EPDO factor</th>
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<tbody>
<tr>
<td>K</td>
<td>$9,145,998</td>
<td>203</td>
</tr>
<tr>
<td>A</td>
<td>$1,012,161</td>
<td>22</td>
</tr>
<tr>
<td>B</td>
<td>$284,399</td>
<td>6</td>
</tr>
<tr>
<td>C</td>
<td>$135,123</td>
<td>3</td>
</tr>
<tr>
<td>O</td>
<td>$45,140</td>
<td>1</td>
</tr>
</tbody>
</table>

National Highway Traffic Safety Administration (NHTSA) report
## Results and discussion

### EB analysis

<table>
<thead>
<tr>
<th>Treatment</th>
<th>CMF</th>
<th>SE (CMF)</th>
<th>Z Statistic</th>
<th>Confidence Interval</th>
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<td>Two-lane Combined Paved Shoulder (2-4 ft) and Shoulder Rumble Strips</td>
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<td>0.04</td>
<td>6.26</td>
<td>0.64 0.81</td>
</tr>
</tbody>
</table>
CMF limits - 95% Confidence Level

- Combined Effect of Paved Shoulder and Shoulder Rumble Strips (40 sites)
- Combined Effect of Paved Shoulder and Shoulder Rumble Stripes (12 sites)
- Effect of Paved Shoulder (31 sites)
## Results and discussion

- **EPDO scores: NHTSA report from 2014**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Before</th>
<th>After</th>
<th>Percent Reduction (%)</th>
</tr>
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<tr>
<td>Two-lane Combined Paved Shoulder (2-4 ft) and Shoulder Rumble Strips</td>
<td>3519</td>
<td>3386</td>
<td>3.78</td>
</tr>
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<td>Two-lane Combined Paved Shoulder (2-4 ft) and Shoulder Rumble Stripes</td>
<td>1397</td>
<td>1348</td>
<td>3.51</td>
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<tr>
<td>Two-lane Paved Shoulder (2-4 ft)</td>
<td>3796</td>
<td>3391</td>
<td>10.67</td>
</tr>
</tbody>
</table>
## Results and Discussion

### B/C analysis

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Total Benefits</th>
<th>Total Costs</th>
<th>B/C ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two-lane Combined Paved Shoulder (2-4 ft) and Shoulder Rumble Strips</td>
<td>$90,577,462</td>
<td>$19,816,155</td>
<td>4.57</td>
</tr>
<tr>
<td>Two-lane Combined Paved Shoulder (2-4 ft) and Shoulder Rumble Stripes</td>
<td>$20,849,098</td>
<td>$5,777,951</td>
<td>3.61</td>
</tr>
<tr>
<td>Two-lane Paved Shoulder (2-4 ft)</td>
<td>$91,967,600</td>
<td>$15,961,356</td>
<td>5.76</td>
</tr>
</tbody>
</table>
Conclusions

- EB analysis:
  - CMFs:
    - 0.79: combined effect of paved shoulder and shoulder rumble strips
    - 0.82: combined effect of paved shoulder and shoulder rumble stripes
    - 0.72: paved shoulder only
    - All treatments reduce ROR crashes, and the CMFs are consistent with the ones commonly found in the literature
Conclusions

- EB analysis:
  - CMFs:
    - 0.79: combined effect of paved shoulder and shoulder rumble strips
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    - 0.72: paved shoulder only
    - All treatments reduce ROR crashes, and the CMFs are consistent with the ones commonly found in the literature

**HOWEVER:**
- A comparison between treatments is not recommended as the confidence intervals for the CMFs overlap
Conclusions

- **EPDO analysis reduction:**
  - 3.78%: combined effect of paved shoulders and shoulder rumble strips
  - 3.51%: combined effect of paved shoulders and shoulder rumble stripes
  - 10.67%: paved shoulder only

- **Limitations of the EPDO method:**
  - Does not account for RTM bias
  - Can overemphasize locations with a small number of severe crashes
  - Does not account for traffic volume

- **Advantages of the EPDO method:**
  - Easy to be applied
  - Accounts for severity of crashes
Conclusions

- B/C ratios:
  - 4.57: combined effect of paved shoulder and shoulder rumble strips
  - 3.61: combined effect of paved shoulder and shoulder rumble stripes
  - 5.76: paved shoulder only
Recommendations

- All treatments were implemented in 2006 or later, there is not much availability of “after” crash data in this study.
- For analyses regarding the comparison between treatments, a following study with more data is recommended.
- All three methods of safety effectiveness evaluation showed that ROR crashes are reduced by all three implemented countermeasures.
- Based on the available data and resulting CMFs, EPDO scores and B/C ratios, it is recommended that ALDOT continues implementing the policy.
Questions?