Pavement Markings to Reduce Lane Departure Crashes

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10 years ago...

- Agencies “liked” the looks of wider edge lines but did not have evidence to support broad implementation.
- Implemented mostly on Interstate and similar highways
- Limited operations-based research results were inconsistent
  - Speed, lateral position
- Human factors studies were simulator-based studies not transferable
- Safety impacts were not well understood
  - Until now, no significant results
  - Naïve before-after crash studies
  - Insufficient data and lack of experimental control
Wide Pavement Markings (2006)

- No Response (21 states)
- Not implemented (7 states)
- Implemented (22 states)

White = no response, Grey = implemented, Grid = not implemented

Mostly Interstate Highways
Fresh Insights

• A compilation of new data since 2006 provides evidence that wider edge lines increase safety
• FHWA has completed a 5 year study that included a safety evaluation of wide edge line markings
• Follow up research was also conducted to fill in the gaps
• Confirmation through case study
Wider Lines v. Brighter Lines

- Wider edge lines provide more benefit than very high retro levels
- “wider edge lines provide a more comfortable driving environment for drivers”
- “wider edge lines provide more time for drivers to focus on critical driving tasks”
- FHWA/TX-10/5862-1

TTI Eye-Tracking Research
SAFETEA-LU Study

Safety Effects of Wider Edge Lines on Rural, Two-Lane Roads

2006-2011
Statewide Retrospective Crash Analysis of Wider Edge Lines

• Nationwide survey
  – Do you use wider edge lines?
  – Where?
  – When?
  – Available crash data?

• Michigan, Illinois, Kansas
Summary of Safety Effects

• For Two-Lane Rural Highways

<table>
<thead>
<tr>
<th>Crash Type</th>
<th>Percent Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>15.0 – 30.1</td>
</tr>
<tr>
<td>Fatal and Injury</td>
<td>15.4 – 37.7</td>
</tr>
<tr>
<td>Day</td>
<td>12.0 – 29.1</td>
</tr>
<tr>
<td>Night</td>
<td>-2.4 – 30.7</td>
</tr>
</tbody>
</table>

• Based on data from 3 states:
  – Kansas from 2001-2007, 1300 miles
  – Michigan from 2001-2009, 788 miles
  – Illinois from 2001-2006, 287 miles

• References:
  – Full: FHWA-HRT-12-048
  – Summary: AAP 2012
Install Wider Edge Lines (4 to 6 inches)

<table>
<thead>
<tr>
<th>CMF</th>
<th>CRF(%)</th>
<th>Quality</th>
<th>Crash Type</th>
<th>Crash Severity</th>
<th>Area Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.635</td>
<td>36.5</td>
<td>★★★★☆☆</td>
<td>All</td>
<td>Fatal, Serious injury, Minor injury</td>
<td>Rural</td>
</tr>
<tr>
<td>0.585</td>
<td>41.5</td>
<td>★★★★★☆</td>
<td>Day time</td>
<td>Fatal, Serious injury, Minor injury</td>
<td>Rural</td>
</tr>
<tr>
<td>0.873</td>
<td>12.7</td>
<td>★★★★☆☆</td>
<td>Nighttime</td>
<td>Fatal, Serious injury, Minor injury</td>
<td>Rural</td>
</tr>
</tbody>
</table>
Comparative B/C Analysis

• Crash data from Kansas DOT
  – fatal and injury crash data
• Crash cost data from NHTSA’s *Economical & Societal Impact of Motor Vehicle Crashes*
  – Fatal = $9,145,998
  – Injury = $1,573,306
  – PDO = $3,862
• Pavement markings
  – waterborne paint
  – $0.15 per foot for 6-in markings
  – 2 year service life
# Comparative B/C Findings

*(Two-Lane Highways)*

<table>
<thead>
<tr>
<th>Treatment</th>
<th>B/C Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wider Edge Lines</td>
<td>$33 - $55 per $1</td>
</tr>
<tr>
<td>Rumble Strips</td>
<td>$37 - $46 per $1</td>
</tr>
<tr>
<td>Chevrons</td>
<td>$9 - $46 per $1</td>
</tr>
<tr>
<td>RRPMs</td>
<td>$13 per $1</td>
</tr>
</tbody>
</table>

- Reference: [AGBMA 2012](#)
Summary

• Eye-Tracking: wide edge lines provide “safer” driver conditions (more time for driver to focus on other critical tasks)
• Speeds: Negligible
• Lane position: Negligible
• Safety: 4 star CMFs ranging from 0.585 to 0.873
• Cost: 15% more
• Cost effectiveness: $1 spent → $33 to $55 benefits
• Automated vehicles: easier detection and tracking for lane departure warning (LDW) and lane keeping assistance (LKA)
Case Study: Missouri DOT

• Smooth Roads Initiative (2005-2006)
  – 2,300 miles of roadways were improved
  – Focus: Rideability and Visibility
  – Visibility ➔ Striping & Delineation
    • Wider markings
    • Rumble strips with wider markings
    • Barrier delineators
    • Reference markers on Interstates
Missouri B/C Findings

• Wider markings (6-inch)
  – urban multilane divided highways (B/C = 29)
  – rural freeways (B/C = 24)
  – urban multilane undivided highways (B/C = 22)

• Wider markings (6-inch) w/ resurfacing
  – rural multilane undivided highways (B/C = 146)
  – urban two-lane highways (B/C = 118)
  – Center line and edge line rumble strips on rural two-lane highways (B/C = 36)
Reference Materials

• Evaluation of Potential Benefits of Wider and Brighter Edge Line Pavement Markings, FHWA/TX-10/5862-1, July 2010
• Benefit/Cost Evaluation of MoDOT’s Total Striping and Delineation Program: Phase II, MRIGlobal, Report CM 12-002, June 2011
• Safety Effects of Wider Edge Lines on Rural Two-Lane Highways, Accident & Analysis Prevention, January 2012.
• An Evaluation of the Effectiveness of Wider Edge Pavement Markings, American Glass Bead Association, February 2012.
• FHWA Safety Newsletter, 2013, Volume 7, Issue 1
Status of Wide Markings

• Implementation since 2016
  – Statewide: Arkansas, West Virginia, California*
  – Partial: Louisiana, Nevada**, Colorado
  – Considering: New Hampshire
  – Under Further Study: North Carolina**

* Automated vehicles (NCHRP 20-102)
** For non-Interstate highways
Evaluation - Profiled Thermoplastic Markings

- TxDOT Atlanta District
- Road Surface
  - PCC
  - New Asphalt
  - Worn Asphalt
  - Seal Coat
- Vehicles
  - Passenger car
  - Pickup truck
- Speed
  - 55 and 70 mph

- Performance Measures
  - Interior sound
  - Interior vibration
  - Exterior sound

- TxDOT Study
  - FHWA/TX-15/9-1001-14-2
  - July 2016
4-in Profiled Thermoplastic Markings

CLRS w Rumble Bars

ELRS w Rumble Bars
Findings

• Center line treatments
  – Interior noise – Alternatives were similar to CLRS
  – Interior vibration – Alternatives were similar to CLRS
  – Exterior noise – Mixed results

• Edge line treatments
  – Interior noise – Alternatives were not as effective as SRS
  – Interior vibration – Alternatives were similar to SRS for pickup but not as effective for car
  – Exterior noise – Mixed results
Safety and Performance Criteria for Retroreflective Pavement Markers

NCHRP Project 05-21
Objective

• Develop practitioner guidelines for RRPMs that include:
  
  – 2-lane rural, urban multi-lane, limited access, and other roads in urban and rural areas
  – Tangent and horizontal curve sections
  – Use of RPMs in conjunction with other types of roadway delineation devices, roadway surface treatments, and lighting and their impacts on driver performance
  – The visibility needs of drivers, particularly those 60 years of age or older
  – Various types of RPMs, i.e., recessed, raised, snow-plowable, etc.
  – Development of performance measures and minimum RPM performance level
Research Approach

• Review Standards and Research (TTI)
• Human Factors – Visibility Study (TTI)
• Visibility Modeling (TTI)
• SHRP2 Driver Behavior (Iowa State - CTRE)
• Safety Analyses (UNC - HSRC)
Questions

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