Lane Reduction Signs for Work Zones
Alternatives to the MUTCD W4-2

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MUTCD W4-2 LANE ENDS Sign
Familiar, but how effective?
Existing MUTCD Signage

Practitioner Concerns

W4-2
- Widely used
- Questionable comprehension
- Not suitable for interior closures

W9-3
- Rarely used
- Four lines of text!
Study Objectives
Is there a better option?

• **Review** previous lane reduction signage comprehension studies.
• **Identify** alternate sign faces used in U.S. and internationally.
• **Develop** possible new signage designs.
• **Evaluate** comprehension using ANSI testing process.
• **Recommend** signs meriting further evaluation.
## W4-2 Evolution & Comprehension 1948-2009

<table>
<thead>
<tr>
<th>Study</th>
<th>Year</th>
<th>Location</th>
<th>Sample Population</th>
<th>Method</th>
<th>Sample Size</th>
<th>Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hawkins, Womack et al.</td>
<td>1995</td>
<td>Texas</td>
<td>Licensed Drivers</td>
<td>Multiple Choice</td>
<td>1745</td>
<td>&lt;66%</td>
</tr>
<tr>
<td>Stokes, Rys et al.</td>
<td>1996</td>
<td>Kansas</td>
<td>Licensed Drivers</td>
<td>Multiple Choice</td>
<td>500</td>
<td>74%</td>
</tr>
<tr>
<td>Dewar, Kline et al.</td>
<td>1997</td>
<td>AB, ID, TX</td>
<td>Drivers Age 18+</td>
<td>Open-Ended</td>
<td>480</td>
<td>38%</td>
</tr>
<tr>
<td>Ford and Picha</td>
<td>2000</td>
<td>Texas</td>
<td>Drivers Ed Students</td>
<td>Multiple Choice</td>
<td>260</td>
<td>50%</td>
</tr>
</tbody>
</table>
W9-3 and W9-3a

W9-3a graphic withdrawn in 2009.
Alternatives to the W4-2
U.S. States and International Practices

- Delaware & Maryland
- Iowa, Minnesota & Missouri
- Quebec: 2:1 Closure
- Vienna Convention A1b (UK)

- G12a 3:2 Closure (France)
- G12b 3:2 Closure (UK)
- Sweden: 3:2 Closure
- New Zealand: 3:2 Closure

- Thailand: 2:1 Closure
- Taiwan: Advance Warning
- Taiwan: Center Closure
- Taiwan: Inside Closure
Field Examples

**Minnesota**
Photo: [Minnesota DOT](#)

**Quebec**
Photo: [SAAQ](#)
Literature Review Summary

Existing MUTCD Lane Closure Signage
• Low comprehension of W4-2
• W9-3a center lane closure graphic failed/withdrawn
• Limited visibility distance for text-based alternatives
• Existing signage not extensible to interior lane closures on segments with 4 lanes or more

Several Alternatives Exist
• U.S. States
• Vienna Convention G12a and G12b
• Other international designs
Testing Safety Graphic Comprehension
ANSI Z535.3

Scope
• General test procedure for safety graphics
• Minimum of 50 representative product users

Acceptance Threshold
• At least 85% correctly understand the graphic.
• No more than 5% “critical confusion.”

What is “Critical Confusion”?
• The sign provokes the opposite of the intended action.
• In this case: instead of exiting the closed lane, a driver thinks they should enter it.
Three-Stage Process

• Stage 1: Preliminary screening (ranking/rating)
• Stage 2: Multiple-choice comprehension test
• Stage 3: Open-ended comprehension test

Implementation

• Surveys and quizzes at DMV offices in WI and IA
Stage 1 Surveys
Road User Preferences

- Sign ratings
- Demographics
Stage 1A Candidates & Results
Road User Ratings Two-to-One Closure Signs

Rating Scale
1: Excellent
2: Good
3: Fair
4: Poor
5: Unacceptable

<table>
<thead>
<tr>
<th>Sign Description</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left Lane Ends</td>
<td>3.58 ± 1.26</td>
</tr>
<tr>
<td>Merge</td>
<td>2.65 ± 1.18</td>
</tr>
<tr>
<td>Merge</td>
<td>3.34 ± 1.24</td>
</tr>
<tr>
<td>Merge</td>
<td>1.53 ± 0.64</td>
</tr>
<tr>
<td>Merge</td>
<td>2.38 ± 1.15</td>
</tr>
<tr>
<td>Merge</td>
<td>3.49 ± 1.25</td>
</tr>
<tr>
<td>Merge</td>
<td>3.65 ± 1.21</td>
</tr>
<tr>
<td>Merge</td>
<td>2.98 ± 1.22</td>
</tr>
<tr>
<td>Merge</td>
<td>2.94 ± 1.31</td>
</tr>
<tr>
<td>Merge</td>
<td>2.30 ± 1.16</td>
</tr>
</tbody>
</table>
Stage 1A Results
Road User Ratings of Graphic Variations

**SIMILAR**

- 2.44 ± 1.17
- 2.30 ± 1.16

**SAME**

- 3.03 ± 1.16
- 3.04 ± 1.14

**SAME**

- 3.02 ± 1.18
- 3.03 ± 1.19

**DIFFERENT?**

- 3.58 ± 1.11
- 3.73 ± 1.02
Stage 1A Results
Road User Ratings of Graphic Variations

- Quebec curved arrow more understandable than New Zealand twin arrows
  Performance for road sign simplicity:

<table>
<thead>
<tr>
<th>Sign</th>
<th>Rating ± Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quebec Curved Arrow</td>
<td>3.33 ± 1.20</td>
</tr>
<tr>
<td>New Zealand Twin Arrows</td>
<td>3.59 ± 1.00</td>
</tr>
<tr>
<td></td>
<td>3.66 ± 1.04</td>
</tr>
<tr>
<td></td>
<td>3.66 ± 1.07</td>
</tr>
<tr>
<td>Quebec Straight Arrow</td>
<td>2.90 ± 1.18</td>
</tr>
<tr>
<td>New Zealand Twin Arrows</td>
<td>3.26 ± 1.08</td>
</tr>
<tr>
<td></td>
<td>3.38 ± 1.09</td>
</tr>
<tr>
<td></td>
<td>3.41 ± 1.15</td>
</tr>
</tbody>
</table>
Stage 1A Results
Backplate Shape

- Rectangular backplate did not appear to affect preferences.
- Graphic fits better on rectangular plate when 3 or more lanes.

2.65 ± 1.18
3.04 ± 1.14
2.90 ± 1.18
Stage 1B Candidates & Results
Road User Ratings of Signs for Center Lane Closures

Rating Scale
1: Excellent
2: Good
3: Fair
4: Poor
5: Unacceptable
Stage 1B Candidates & Results
Road User Ratings of Signs for Center Lane Closures

Rating Scale
1: Excellent
2: Good
3: Fair
4: Poor
5: Unacceptable

2.94 ± 1.24
3.35 ± 1.20
1.36 ± 0.78
3.76 ± 1.08
3.46 ± 1.16
3.98 ± 1.17
3.06 ± 1.22
2.98 ± 1.36
3.43 ± 1.41
## Stage 2 Results
### Multiple-Choice Testing

<table>
<thead>
<tr>
<th>Sign</th>
<th>Response</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>W4-2 (2003 Version)</strong></td>
<td>Left lane ending – traffic in left lane should merge into right lane (CORRECT)</td>
<td>67%</td>
</tr>
<tr>
<td></td>
<td>Median between opposing traffic will end</td>
<td>19%</td>
</tr>
<tr>
<td></td>
<td>Lanes narrow ahead</td>
<td>11%</td>
</tr>
<tr>
<td></td>
<td>Left lane ending – traffic in right lane should yield to left lane.</td>
<td>3%</td>
</tr>
</tbody>
</table>

Responses: n = 102

<table>
<thead>
<tr>
<th>Sign</th>
<th>Response</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>G12a with Quebec Style Arrows and Red Trapezoid</strong></td>
<td>Center lane ends, merge to the right lane (CORRECT)</td>
<td>82%</td>
</tr>
<tr>
<td></td>
<td>Avoid obstacle on the road</td>
<td>11%</td>
</tr>
<tr>
<td></td>
<td>Center lane ends, merge to the left lane</td>
<td>5%</td>
</tr>
<tr>
<td></td>
<td>Traffic in center lane should stop</td>
<td>2%</td>
</tr>
</tbody>
</table>

Responses: n = 95
## Stage 2 Results
### Multiple-Choice Testing

<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
<th>Percentage</th>
<th>Correct Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upward Drop Arrow with White Border</td>
<td>Responses: n = 94</td>
<td>77%</td>
<td>Left lane ending – traffic in left lane should merge into right lane (CORRECT)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10%</td>
<td>Left lane ending – traffic in right lane must yield to left lane.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9%</td>
<td>Lanes narrow ahead</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5%</td>
<td>Lanes shift ahead</td>
</tr>
<tr>
<td>G12a with Quebec Style Arrows</td>
<td>Responses: n = 102</td>
<td>64%</td>
<td>Merging traffic entering from the left</td>
</tr>
<tr>
<td></td>
<td></td>
<td>28%</td>
<td>Left lane ending – traffic in left lane should merge into right lane (CORRECT)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8%</td>
<td>Left lane ending – traffic in right lane must yield to left lane.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0%</td>
<td>Narrow lanes ahead – reduce speed</td>
</tr>
</tbody>
</table>
# Stage 2 Results

## Multiple-Choice Testing

### Horizontal Arrow

<table>
<thead>
<tr>
<th>Response</th>
<th>Percentage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detour ahead, turn right</td>
<td>62%</td>
<td></td>
</tr>
<tr>
<td>Road ahead makes a sharp right turn</td>
<td>18%</td>
<td></td>
</tr>
<tr>
<td>Lanes shift to the right</td>
<td>11%</td>
<td></td>
</tr>
<tr>
<td>Lane ends, merge to the right (CORRECT)</td>
<td>9%</td>
<td></td>
</tr>
</tbody>
</table>

Responses: n = 95

### Two Parallel Arrows with Worker Symbol

<table>
<thead>
<tr>
<th>Response</th>
<th>Percentage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workers in left shoulder</td>
<td>42%</td>
<td></td>
</tr>
<tr>
<td>Intermittent work activity in left lane</td>
<td>27%</td>
<td></td>
</tr>
<tr>
<td>Snow removal/plow in left lane</td>
<td>25%</td>
<td></td>
</tr>
<tr>
<td>Left lane ending – traffic in left lane should merge into right lane (CORRECT)</td>
<td>6%</td>
<td></td>
</tr>
</tbody>
</table>

Responses: n = 101
Stage 3 Finalists
Stage 3 Testing
Open-Ended Questions

This survey is being done by the Traffic Operations & Safety Laboratory at the University of Wisconsin–Madison. We are studying driver comprehension of proposed traffic signs. For each sign, please describe in your own words what that sign means to you. The research is sponsored by the Smart Work Zone Deployment Initiative. If you have questions about this project, contact Dr. Madhav Chitturi 608-890-2439.

What does this sign mean to you?


What does this sign mean to you?


About You…

Do you have a driver license or permit?
- Yes
- Came to the DMV today to apply for license or permit
- No

What is your primary language?
- English
- Spanish
- Hmong
- Other (please specify)

Which best describes your gender:
- Man
- Woman

Age
- 13 or Younger
- 14-16
- 17-18
- 19-24
- 25-34
- 35-44
- 45-54
- 55-64
- 65-74
- 75-84
- 85 or Older

Approximately how many hours do you drive each week?
- 5 or Less
- 6 to 10
- 11 to 15
- 16 to 20
- 21 to 25
- 26 to 30
- 31 to 35
- 36 to 40
- 40 or more

Thank you for your participation!
### Stage 3 Testing

#### Open-Ended Questions

<table>
<thead>
<tr>
<th>Sign</th>
<th>Response</th>
<th>Response Example</th>
<th>Percent of Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Upward Drop Arrow with White Border</strong></td>
<td>Correct</td>
<td>“Two lane goes down to one lane w/ right lane continuing”</td>
<td>67%</td>
</tr>
<tr>
<td></td>
<td>Partially Correct</td>
<td>“Lane ending”</td>
<td>28%</td>
</tr>
<tr>
<td></td>
<td>Incorrect</td>
<td>“Road gets narrow”</td>
<td>5%</td>
</tr>
<tr>
<td></td>
<td>Critical Confusion</td>
<td>None identified</td>
<td>0%</td>
</tr>
<tr>
<td><strong>G12a with Quebec Style Arrows and Red Trapezoid</strong></td>
<td>Correct</td>
<td>“Three lanes narrow to two (same direction). Middle lane merges to the right lane; middle lane becomes closed.”</td>
<td>37%</td>
</tr>
<tr>
<td></td>
<td>Partially Correct</td>
<td>“A median or obstacle is in the middle lane”</td>
<td>28%</td>
</tr>
<tr>
<td></td>
<td>Incorrect</td>
<td>“Keep straight/slight right”</td>
<td>35%</td>
</tr>
<tr>
<td></td>
<td>Critical Confusion</td>
<td>None identified</td>
<td>0%</td>
</tr>
<tr>
<td>Sign</td>
<td>Multiple Choice</td>
<td>Open-Ended</td>
<td></td>
</tr>
<tr>
<td>------</td>
<td>----------------</td>
<td>------------</td>
<td></td>
</tr>
<tr>
<td><img src="image1" alt="Sign" /></td>
<td>67%</td>
<td>Not Tested</td>
<td></td>
</tr>
<tr>
<td><img src="image2" alt="Sign" /></td>
<td>77%</td>
<td>95%</td>
<td></td>
</tr>
<tr>
<td><img src="image3" alt="Sign" /></td>
<td>82%</td>
<td>65%</td>
<td></td>
</tr>
</tbody>
</table>
Derivation
Existing W4-2 to Upward Drop Arrow
Potential Applications

Upward Drop Arrow

a. Upward Drop Arrow as tested in this study
b. Upward Drop Arrow with supplemental text plaque
c. Permanent lane reductions
d. Incident management
Potential Applications
Americanized G12a Sign

a. As Tested
b. With supplemental text plaque
c. Left Lane Closure
d. Third lane closure
e. Advance warning
f. Regulatory
Field Testing Recommendations
FHWA “Request to Experiment” Approval Required
Acknowledgements

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• Iowa, Kansas, Missouri, Nebraska & Wisconsin DOTs
• FHWA Midwest Resource Center
• Project Technical Advisory Committee

Survey & Test Distribution
• Wisconsin DMV (Greenfield, Madison East, Madison West, Milwaukee Northeast)
• Iowa DMV (Dubuque)
• 397 DMV customers
Project Team

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