NCHRP 13-02
Development of Guidelines for Warning Lights on Maintenance Vehicles

Dr. Ronald B. Gibbons
NCHRP Project 13-02

- **Purpose**
  - Develop guidelines for the selection and application of warning lights to improve the conspicuity and recognizability of roadway-operations equipment used for construction, maintenance, utility work, and other similar activities
Background

- There is a wide disparity in roadway maintenance vehicle warning lights
- This inconsistency raises problems of proper interpretation of their meaning
- No single study has tried to provide a comprehensive guideline for the marking of maintenance vehicles
- The impact of weather on the conspicuity and visibility of vehicles has also not been investigated
Purpose of Warning Lights

- Warn motorists that a highway maintenance vehicle is on or near the roadway
- Allow drivers to take actions with enough warning time
- To define the shape and size of the vehicle
- To convey the intent of the vehicle
Dynamic Performance Experiment

- Factors Tested:
  - Ambient Lighting Conditions
  - Weather
  - Visual Complexity
  - Light Position
  - Driver Expectancy
  - Distraction

- All of the experiments were conducted on the VTTI Smart Road
  - Rain, Clear and Fog weather conditions
  - Day and Night
  - 4 Sessions were required for the experiment

- An uniformed event was used at the beginning of the testing to test some of the characteristics

- 32 Participants (16 between 25 and 35 and 16 over 65)
  - Each saw 116 lighting and ambient conditions
Vehicle Setup

- The same dump truck from the Screen Experiment was used
  - The four lighting conditions were mounted on the vehicle
- The system could be controlled by the driver
- All of the patterns were asynchronous with a 1 Hz frequency
Nighttime Road Setup

Ratings

Pedestrian Testing
Daytime Road Setup

Daytime Dry

0 ft (Experimental Vehicle)

1200 ft (Yellow cone)

2400 ft (White cone)

3600 ft (Green cone)

4800 ft (Blue cone)

Participant Vehicle Facing Downhill

Daytime Dry

4800 ft (Blue cone)

3600 ft (Green cone)

2400 ft (White cone)

1200 ft (Yellow cone)

0 ft (Experimental Vehicle)

Participant Vehicle Facing Uphill
Dependent Variables

- Uninformed Test
  - Lane Change Distance
  - Attention-Getting

- Smart Road Testing
  - Vehicle Identification Distance
    - Participants stated when they were sure that they were approaching a vehicle
  - Pedestrian Detection Distance
    - Distance at which a pedestrian beside the vehicle could be seen
    - Nighttime only
  - Attention-Getting
    - 7 Point Scale
  - Confidence
    - Rating from 0 to 100
    - Daytime only
  - Discomfort Glare
    - 9 Point Scale with 9 being the highest
    - Nighttime only
  - Urgency
    - Rating from 0 to 100
Pedestrian Position

- The pedestrian was located at rear of the truck in the center of the approach lane
  - They were wearing Denim Scrubs and a retroreflective vest
Daytime Truck Appearance

Downhill against Background

Uphill against Sky
Draft Guidelines

- Guidelines were developed based on the experimental results
- The document is currently being put into its final form by NCHRP
- Document includes guidelines and draft specifications
Draft Guidelines

- **Lighting Characteristics**
  - Lighting Systems with a profiled Output provided better vehicle identification
  - 360° Sources should be avoided close to the line of sight

- **Adverse Weather**
  - LED systems had increased scatter and caused decreased detection distances

- **Color**
  - The lighting should be amber in color

- **Lighting System Layout**
  - The Lights should appear against a controlled background not the sky

- **Other Factors**
  - Other vehicles and roadway lighting will generally reduce the impression of glare from the lighting system
Impact of Weather on Vehicle Identification

Vehicle Identification Distance - Weather and Warning Light

![Graph showing the impact of weather on vehicle identification distance for different warning lights in dry, rain, and fog conditions. The graph compares High-Mounted Beacon, Low-Mounted Beacon, LED, and Strobe.]
Results – Uninformed Trial

Lane-Change Distance - Warning Light

<table>
<thead>
<tr>
<th>Warning Light</th>
<th>Distance (ft)</th>
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</thead>
<tbody>
<tr>
<td>High-Mounted Beacon</td>
<td>150 ± 20</td>
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<tr>
<td>Low-Mounted Beacon</td>
<td>160 ± 25</td>
</tr>
<tr>
<td>LED</td>
<td>250 ± 30</td>
</tr>
<tr>
<td>Strobe</td>
<td>180 ± 25</td>
</tr>
</tbody>
</table>
Weather and Glare

Discomfort Glare Rating - Warning Light and Weather

![Discomfort Glare Rating Chart]

<table>
<thead>
<tr>
<th>Warning Light</th>
<th>Discomfort Glare Rating (1-9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-Mounted Beacon</td>
<td>3.5 (Dry), 3.8 (Rain), 4.2 (Fog)</td>
</tr>
<tr>
<td>Low-Mounted Beacon</td>
<td>3.9 (Dry), 4.1 (Rain), 4.5 (Fog)</td>
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<tr>
<td>LED</td>
<td>5.0 (Dry), 5.2 (Rain), 5.5 (Fog)</td>
</tr>
<tr>
<td>Strobe</td>
<td>4.0 (Dry), 4.3 (Rain), 4.7 (Fog)</td>
</tr>
</tbody>
</table>
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Weather – Pedestrian Detection

Pedestrian Detection Distance - Warning Light and Weather

![Pedestrian Detection Distance Chart](chart.png)
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Vehicle Identification

% of Responses

Vehicle Activity

<table>
<thead>
<tr>
<th>Activity</th>
<th>High Amber</th>
<th>High Blue</th>
<th>High Red</th>
<th>High White</th>
<th>Low Amber</th>
<th>Low Blue</th>
<th>Low Red</th>
<th>Low White</th>
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<tbody>
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<td>Medical Response</td>
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Impact of Appearance against Sky

Attention-Getting Rating - Warning Light and Direction

- High-Mounted Beacon
- Low-Mounted Beacon
- LED
- Strobe

Downhill
Uphill
Draft Guidelines

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Photometric Comparison

- The photometric and screening results were used to define limits for the photometric quantities allowed for the lighting system
  - This is a balance between the conspicuity measures and the glare rankings
    - The limits for daytime and nighttime Performance would be different
    - Glare limits are between 5 and 6 ranking level
Daytime Conspicuity

Mean Daytime Attention-Getting Rating by Light Source Intensity for Panel Lights by Light Type and Color

- Halogen Amber
- LED Amber
- Strobe Amber

Intensity (Form Factor Method) vs. Attention-Getting Rating (1-7)
Nighttime Conspicuity

Mean Nighttime Attention-Getting Rating by Light Source Intensity for Panel Lights by Light Type and Color

- Halogen
- LED Amber
- Strobe Amber

Intensity (Form Factor Method)

Attention-Getting Rating (1-7)
Glare Limits

Mean Discomfort Glare Rating by Light Source Intensity for Panel Lights by Light Type and Color

Discomfort Glare Rating (1-9)

Intensity (Form Factor Method)
Draft Intensity Limits

<table>
<thead>
<tr>
<th>Photometric Limits</th>
<th>Intensity (by Form Factor Method)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Daytime</td>
</tr>
<tr>
<td>Light Source</td>
<td>Minimum</td>
</tr>
<tr>
<td>Halogen</td>
<td>3500</td>
</tr>
<tr>
<td>LED</td>
<td>4000</td>
</tr>
<tr>
<td>Strobe</td>
<td>3500</td>
</tr>
</tbody>
</table>
Contact

- Any questions or comments associated with this project or the draft results should be directed to the National Cooperative Highway Research Program (NCHRP)
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