Speed Impacts of an Icy Curve Warning System

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Overview

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- Past work
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- Conclusions
Introduction

• Caltrans continually identifies and remedies safety challenges in its infrastructure
• One location identified by Caltrans District 2 was a five-mile segment of Fredonyer Pass
• Section of roadway had history as high-crash location
• Speeding a major cause of accidents, which occurred when pavement was icy
  – Static signage previously installed to increase awareness
• Based on the crash history, Caltrans deployed Icy Curve Warning System (ICWS) to reduce ice-related accidents
System Layout

- Five-mile section PM 9.5 - PM 14.5
- Two Extinguishable Message Signs used in each direction to warn motorists (“Icy Curves Ahead”)
- Three ice detection sensors installed for the system.
  - Sensor 1 located in curve at top of grade, sensors 2 and 3 located in curve that tends to stay wet due to the trees present on both sides of the road
- For each system, two EMS activated if ice is detected or predicted by one of the ice and ESS sensors
- Complete system considered operational and reliable beginning with the winter season of 2008-2009
- Objective of this study was to evaluate effects of the ICWS on vehicle speeds under different conditions
System Layout cont’d
Past Work

- Oregon (2005) - Oregon Highway 140 ice warning system
  - Mean speeds fell 9.5 mph overall (eastbound by 10.4 mph, westbound by 8.4 mph) when signs on
- Wyoming (2001) - Nugget Canyon ice warning system
  - Mean speeds dropped 5 to 10 mph when signs on
- Idaho (1993) – I-84 weather warning system
  - Mean speeds dropped 20 mph during high winds and extreme weather
- Utah (2000s) – visibility warning system
  - Standard deviation of speeds decreased before and after by 22 percent
- Finland (1992) – condition warning system
  - When slippery road present mean speeds dropped by 1.5 mph
Data

• Continuous radar speed data collected by Caltrans near beginning of each set of curves

• System status (displaying ice warning or not)

• Road Weather Information System data from site on the pass to characterize prevailing conditions
  – Used to establish when clear and cold conditions with the potential for ice formation were present at the site
Methodology

• Two-sample t-test (unequal variance) employed to compare vehicle speeds between system conditions/states
  – Speed thresholds of 0, 3 and 5 mph evaluated
  – 0.025 and .05 levels of significance employed

• Evaluation scenarios:
• On versus off
• Day versus night
• Weather - during different conditions (wet, clear, cold and dry, etc.), categorized by day and night
• Chain control
Methodology cont’d

• Zero mph condition hypotheses were:
  – $H_0$: $\mu_1 = \mu_2$, mean speeds between non-icy and icy conditions not significantly different
  – $H_1$: $\mu_1 \neq \mu_2$, mean speeds are significantly different
• 3 and 5 mph hypotheses were:
  – $H_0$: $\mu_1 - \mu_2 \geq 3$ or $5$, difference between mean speeds of more than 3 or 5 mph was significant
  – $H_1$: $\mu_1 - \mu_2 < 3$ or $5$, mean speeds were not significantly different from one another at 3 or 5 mph
• In this work, speed differences between clear, cold and dry and clear, cold and not dry conditions were of greatest interest
  – Clear, cold and not dry conditions represented those where a motorist might not expect ice, but ice was present
Results

• System On versus Off
  – Mean speeds significantly different by greater than 5 mph
  – Ranged from 53 to 57 mph when off, 45 to 50 mph when on

• Day versus Night
  – Differences significantly different by greater than 5 mph during both the day and night when on versus off
  – Mean speed reductions ranged between 5.19 and 8.66 mph during day, 5.72 and 8.30 mph during night
Results cont’d

• System impacts during potentially icy conditions of greatest interest to this work

• Scenarios:

<table>
<thead>
<tr>
<th>Time of Day</th>
<th>Clear, Cold, and Dry</th>
<th>Clear, Cold, but not Dry</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Daytime</strong></td>
<td>• No precipitation</td>
<td>• No Precipitation</td>
</tr>
<tr>
<td></td>
<td>• Surface Temp &lt; 32F</td>
<td>• Surface Temp &lt; 32F</td>
</tr>
<tr>
<td></td>
<td>• Surface Status = Dry</td>
<td>• ICWS is ON</td>
</tr>
<tr>
<td></td>
<td>• ICWS is OFF</td>
<td></td>
</tr>
<tr>
<td><strong>Nighttime</strong></td>
<td>• No precipitation</td>
<td>• No Precipitation</td>
</tr>
<tr>
<td></td>
<td>• Surface Temp &lt; 32F</td>
<td>• Surface Temp &lt; 32F</td>
</tr>
<tr>
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<td>• Surface Status = Dry</td>
<td>• ICWS is ON</td>
</tr>
<tr>
<td></td>
<td>• ICWS is OFF</td>
<td></td>
</tr>
</tbody>
</table>
Results cont’d

• Wet conditions (snow, rain)
• Mean speeds significantly lower when system on by greater than 5 mph
  – Day: mean speeds fell by 6.20 to 10.73 mph when system on
  – Night: mean speeds fell by 10.34 to 16.14 mph when system on
• Differences expected given road conditions and visibility
Results cont’d

- Clear, cold and dry versus clear, cold and not dry (i.e. icy) conditions
- Significant changes in mean speeds observed between on and off system states
  - Exception – March - April 2009 (small sample)
- Night: mean speeds fell by 2.76 to 3.36 mph when system on
- Day: mean speeds fell by 2.91 to 6.80 mph when system on
Results cont’d

• Mean speed differences greater than 3 mph but less than 5 mph observed
• Limited significant mean speed changes greater than 5 mph
  – Large changes in speed (5+ mph) could not entirely be expected until driver entered a curve
• Encouraging that significant changes greater than 3 mph observed
  – Indicates motorists likely changing speed behaviors prior to entering curves
Results cont’d

• Chain control
• Greatest impact of ICWS when R-1 chain control is in effect
  – R-1 requires chains on all commercial vehicles while all other vehicles must have either snow tread tires or chains on drive axle
• Significant changes greater than 0 mph observed when ICWS was on for all sites (excluding Signs 1 and 2 at night)
• Speed differences also greater than 5 mph at all signs
  – Exception - Sign 3 at night - mean speed difference greater than 0 and less than 3 mph
Discussion

• Drivers traveled close to posted speed limit during clear, cold and dry conditions
• Mean speeds significantly lower than posted speed limit during clear, cold and not dry (icy) conditions
  – Speeds were higher than the 40 mph curve speed limit
• Results indicate speed of clear, cold and dry versus clear cold and not dry conditions are significantly different
  – Unknown if mean speed changes observed in advance of the curves translate into reductions within the curves
• Results indicate speed of clear, cold and dry versus clear cold and not dry conditions are significantly different
Conclusions

• Results of statistical analysis suggest vehicle speeds lower when ICWS is on
  – System on versus off: mean speeds significantly different by 5+ mph
  – Day and night: mean speeds significantly differed by 5+ mph when system on
  – General wet weather: mean speeds significantly differed by 5+ mph when system on during day and night
Conclusions

- Clear, cold and not dry conditions
  - Mean speed differences significant by greater than 3 mph when the system was on both during the day and at night
  - Only limited number of speeds significantly different by greater than 5 mph
  - Appears that ICWS is prompting speed reductions of 3 mph in conditions where icy roads are not necessarily expected
- Chain control: ICWS produced significant differences greater than 5 mph under R-1 control
Disclaimer

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Questions