Speed Impacts of an Icy Curve Warning System

David Veneziano and Jared Ye

Western Transportation Institute – Montana State University

Ian Turnbull

Chief, Office of ITS Engineering and Support, Caltrans District 2

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Overview

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Introduction

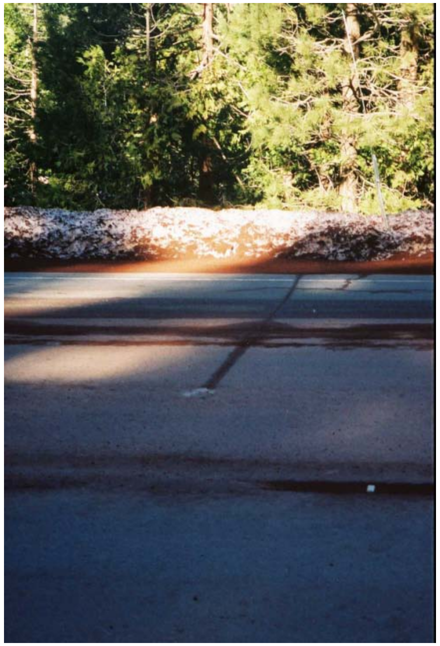
- Caltrans continually identifies and remedies safety challenges in its infrastructure
- One location identified by Caltrans District 2 was a five-mile segment of Fredonyer Pass
- Section of roadway had history as high-crash location

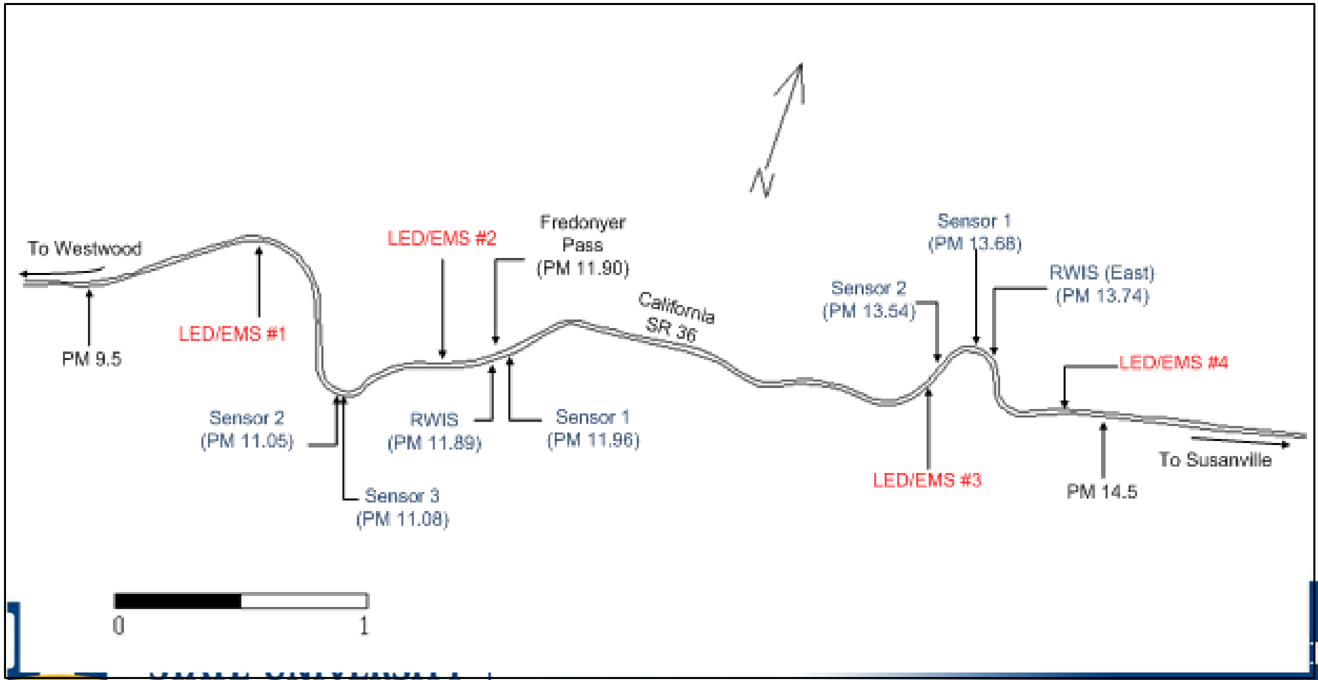
- Speeding a major cause of accidents, which occurred when pavement was icy
  - Static signage previously installed to increase awareness
- Based on the crash history, Caltrans deployed Icy Curve Warning System (ICWS) to reduce ice-related accidents

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
  - Data periods: March 12, 2009 – April 15, 2009, October 1 2009 – March 31, 2010, October 1, 2010 – April 15, 2011
- 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:

Time of Day	Conditions	
	Clear, Cold, and Dry	**Clear, Cold, but not Dry**
Daytime	• No precipitation • Surface Temp < 32F • Surface Status = Dry • ICWS is OFF	• No Precipitation • Surface Temp < 32F • ICWS is ON
Nighttime	• No precipitation • Surface Temp < 32F • Surface Status = Dry • ICWS is OFF	• No Precipitation • Surface Temp < 32F • ICWS is ON

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