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Safety Effects of Icy Curve Warning Systems

Zhirui Ye, David Veneziano and Ian Turnbull

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MONTANA STATE UNIVERSITY
Western Transportation Institute

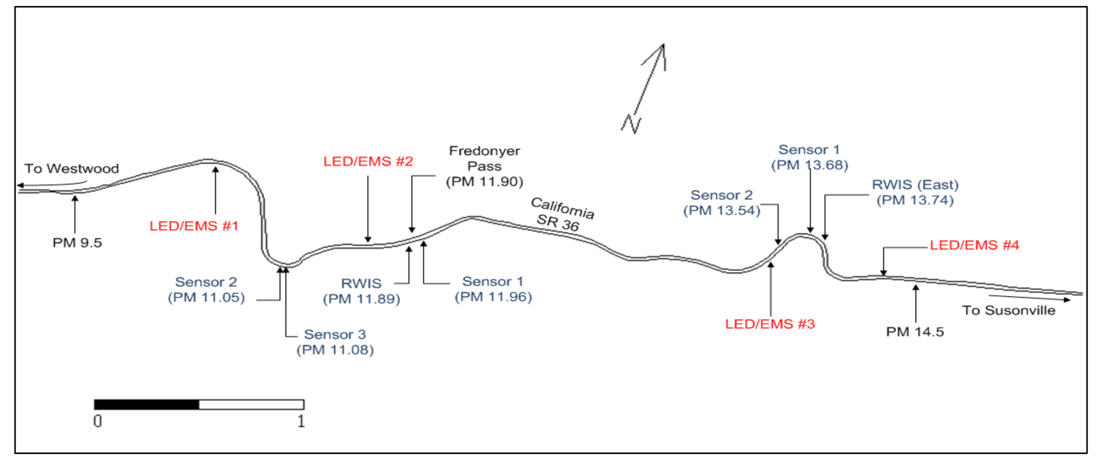
Abstract

The California Department of Transportation (Caltrans) deployed an Icy Curve Warning System (ICWS) on a five-mile section of State Route (SR) 36 in Lassen County over Fredonyer Pass. This section of roadway had a history as a high-crash location, with multiple fatal crashes. The vast majority of these accidents occurred when the pavement was icy, despite static signage that Caltrans had installed to increase motorist awareness.

This study presents the results of research that investigated safety effects of the ICWS. An observational before-after study method with Empirical Bayes technique was used to determine the effect the ICWS on crash frequencies. The results showed that the ICWS reduced annual crashes by 18%. Moreover, analysis of ice-related accidents during winter seasons found that the ICWS had reduced crash severities on this roadway section. Based on these results, a benefit analysis revealed that the ICWS provided an estimated monetary benefit of $1.7 million dollars per winter season to motorists through reduced crashes. The study results are anticipated to contribute to a better understanding of safety effects of ice (or icy curve) warning systems and increase the knowledge base of weather-specific treatments and their associated effects.

Background

The Fredonyer Pass ICWS consists of two identical but separate warning systems: Fredonyer Summit ICWS and Fredonyer East ICWS. The schematic of Fredonyer Pass ICWS is shown in the figure. The technology consists of using pavement sensors to detect icy conditions, in combination with dynamically activated signage, to provide motorists with real-time warning when icy conditions are present.



The following table shows the geometrics of the five-mile highway section. This section is divided into seven segments based on the total number of lanes present and speed limit.

Seg. No.	PM (Begin)	PM (End)	Seg. Length	Lane Width	Total Lanes	No. of Lanes (EB)	No. of Lanes (WB)	Should Width	Speed Limit
1	9.50	10.35	0.85	13	3	2	1	5	55
2	10.35	11.26	0.91	13	3	2	1	5	40
3	11.26	11.76	0.50	13	3	2	1	5	55
4	11.76	12.27	0.51	13	4	2	2	5	55
5	12.27	13.43	1.16	13	3	1	2	5	55
6	13.43	14.10	0.67	13	3	1	2	5	40
7	14.10	14.50	0.40	13	2	1	1	5	55

Study Data

Installation, calibration and testing of the system began in the summer of 2002 and concluded in the summer of 2008. A significant period of this time was spent testing and validating the system to ensure that the various weather and roadway conditions were properly accounted for by the system. Consequently, the ICWS was not considered fully operational and reliable until the winter season of 2008-2009. Thus, 4.5 years of the before period (January 1, 1998 – June 30, 2002) and 1.5 years of the after period data (July 1, 2008 – December 31, 2009) were chosen for safety evaluation.

Crash data were obtained from Caltrans's Traffic Accident Surveillance and Analysis System (TASAS) database and the Highway Safety Information System (HSIS) for the study period. Crash information included date and time, post mile, road surface condition, type of accident, etc., as summarized in the following table.

Period	Year	No of Months	Crashes (ice-related)	PDO (ice-related)	Injury (ice-related)	Fatality (ice-related)	AADT
Before	1998	12	17	8 (5)	8 (5)	1 (1)	2850
	1999	12	9 (6)	9 (6)	0	0	2850
	2000	12	14 (10)	11 (9)	3 (1)	0	2850
	2001	12	8 (5)	5 (3)	3 (2)	0	2900
	2002	6	7 (6)	3 (2)	4 (3)	1 (1)	2950
After	2008	6	3 (3)	1 (1)	2 (2)	0	2850
	2009	12	9 (7)	7 (5)	2 (2)	0	2850

Methodology

This study used **observational before-after study with Empirical Bayes** (EB) to evaluate the safety effects of ICWS. The following Safety Performance Function (SPF) for rural two-lane, two-way roadway segments provided in the Highway Safety Manual (HSM) was used to predicted average crash frequency for base conditions:

$$N_{spf} = AADT * L * 10^{-6} * e^{(312)}$$

Based on the existing geometrics of the Fredonyer Pass highway section, **6 Crash Modification Factors** (CMFs) need to be used to account for the effect of site-specific design features. These CMFs included shoulder width and type, horizontal curves (length, radius, and presence or absence of spiral transitions), horizontal curves (superelevation), grades, passing lanes, and roadside design.

The EB technique was used to estimate the expected crash frequency by combining the predictive model estimate with observed crash frequency. The expected crash frequency for an individual roadway segment is computed by :

$$N_{expected} = w * N_{predicted} + (1 - w) * N_{observed} \qquad w = \frac{1}{1 + k * (\sum_{all\ study\ years} N_{predicted})}$$

where:

$N_{expected}$ = estimate of expected average crash frequency for the study period;
$N_{predicted}$ = predicted model estimate of average crash frequency for the study period;
$N_{observed}$ = observed crash frequency at the site for the study period; and
w = weighted adjustment to be placed on the predictive model estimate.

Results

The number of reported crashes in the after period with the ICWS present: λ = 12 (crashes)
The predicted number of crashes in the after period without the ICWS: π = 14.08 (crashes)
Safety effectiveness of ICWS (θ =**0.82**):

$$\theta = \frac{\lambda/\pi}{1 + Var(\pi)/\pi^2} = \frac{12/14.08}{1 + 7.9/14.08^2} = 0.82$$

Effect on crash severities:

Study Period	Total	Crash Rate (ice-related crashes per winter season) PDO	Injury	Fatality	Fatality + Injury (F+I)
Before	8.38	5.51	2.42	0.44	2.86
After	6.67	4.00	2.67	0	2.67

Conclusions

- ❖ The results revealed that the deployment of the ICWS **reduced the number of annual crashes by 18%**.
- ❖ The use of ICWS have **reduced crash severities**.
- ❖ The system has potentially provided safety benefits of **$1.7 million dollars** per winter season during the "after deployment" study period.
- ❖ Limited after deployment data collected to make any results definitive
- ❖ Data will continue to be collected to update the analysis over the next several years.

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Contact Information

David Veneziano
Research Scientist
Western Transportation Institute
Montana State University
P.O. Box 174250, Bozeman, MT-59717
Phone: 406 994 6320; Fax: 406 994 1697
david.veneziano@coe.montana.edu