Evaluation of an Oregon Ice Detection & Warning System: An ITS Safety Project Implementation

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Abstract

The Butte Creek Ice Warning System was deployed in November 2005 to actively warn motorists of potentially icy driving conditions along a corridor of Oregon's highway 140 (Lake of the Woods Highway) between Medford and Klamath Falls. The system consists of a road weather information system (RWIS) located near the summit of the pass. The RWIS is used to measure environmental conditions and is linked to two static signs with flashing beacons warning travelers of potentially icy conditions. Beacons are located at either side of the Lake of the Woods pass. When threshold conditions are met, the flashing warning beacons activate automatically. During the winter of 2007-08 a study was conducted on the operation of the system. A log of beacon activation events was compiled and compared to speed data. A speed record was obtained from an automatic traffic counter (ATC) with speed measurement capability that is located west of the pass, outside the traditional snow zone. A microwave speed measuring device was installed at the RWIS site which provided a speed record in the snow zone. These two speed records allowed for a comparison of speeds during beacon activation periods. Driver surveys were conducted, both by on-site visits during inclement weather and by means of web-based and mail-out surveys. Finally, an analysis of crash data was conducted using crash reports before and after system implementation. This paper will discuss the advanced warning system and report on the results of the surveys as well as speed and crash data analyses.

Summary

A system for warning drivers of potentially icy road conditions has been implemented on Highway 140 in the Cascade mountain range of southern Oregon. The system consists of a road weather information system (RWIS) located at milepost 35 near the mountain pass and two static signs with flashing beacons located at lower elevation approaches to the pass at mileposts 41.7 and 21.7. Additionally, an automated traffic recorder (ATR) at milepost 16 provided speed data from outside the ice zone. An evaluation of the system was conducted during the winter season of 2007-08. The evaluation consisted of a before-and-after assessment of crash data, a speed study with speeds measured at the RWIS and ATR, and a survey of drivers.

This evaluation of the advanced warning system, as currently configured, produced mixed results. While crash data analyses revealed no decrease in crashes after system implementation, speed data analyses revealed significant reduction in speed between the ATR and RWIS sites while the beacons were flashing. However it is impossible to attribute the observed speed reductions solely to the presence of the warning system. Finally, driver surveys revealed that an overwhelming majority of the population is aware of the beacons. Driver survey results also suggest that people are confident in the beacons. Finally, drivers reported slowing down and being more cautious and attentive when the beacons are flashing.

Background

The state of Oregon is diverse in terms of geography, elevation, and weather and includes highways in both urban and rural settings. The Oregon Department of Transportation (ODOT) employs intelligent transportation system (ITS) technology to benefit road users throughout the state. The project discussed in this paper is an evaluation of an ODOT ice detection and warning system located on a state highway in the southern Cascade Range.

The ice detection and warning system, generally known as the “Butte Creek Ice Warning System” was deployed in late 2005 to actively warn motorists of potentially icy driving conditions.

The system is located on OR 140 (Lake of the Woods Highway) and consists of a road weather information system (RWIS) station located at milepost 35 and two static signs with flashing beacons located at mileposts 41.7 and 21.7. The RWIS is located at an elevation of approximately 5100 ft. near the summit of the Lake of the Woods Pass. The warning beacons are located at lower elevations on both approaches to the pass. When threshold conditions at the RWIS site are met (generally a combination of pavement temperature, humidity and indication of wet pavement status), the flashing beacons are activated. It should be noted that during the study period of 2007-08, the in-pavement sensor was not operational and threshold conditions were based on air temperature and humidity. ODOT has verified that icy conditions exist when these revised threshold conditions are met.

Crash Data Analysis

Crash data from ODOT’s Crash Analysis and Reporting Unit were evaluated over a five year period, 2003-2008. The study section was between mileposts 21.7 and 41.7, the location of the flashing beacons. The crash report files include a road surface code whereby the condition can be reported as one of five states: dry, wet, snow, ice or unknown. Initial review of the data indicated that icing conditions can occur as early as November and as late as April. There were no crashes where the road condition was reported as “unknown” in the five year period.

The five year crash analysis period included two seasons prior to the November 2005 ice warning system installation and three seasons after the installation. A summary of crash data for these periods is shown in Table 1.

Table 1 Crash History for Highway 140 Milepost 21.7-41.7

Date Range	# Reported Crashes	# Reported Crashes w/ ice/snow condition	Ice Warning System Status	Period Averages
Nov. 2003-April 2004	33	30	Not operational	***Before system 43 crashes/season***
Nov. 2004-April 2005	53	45	Not operational	
Nov. 2005-April 2006	77	76	Operational	***After system 51 crashes/season***
Nov. 2006-April 2007	42	40	Operational	
Nov. 2007-April 2008*	34	34	Operational	

*This total represents data from an incomplete 2008 crash data set which will not be complete until late 2009. These data are preliminary and subject to change.

As shown in Table 1 there has been no apparent reduction in crashes since the installation of the warning system, in fact the short term average crashes increased from 43 to 51 average crashes per season after the warning system was installed. However, it must be noted that the length and severity of winter conditions can vary widely from one year to the next which makes direct comparison of crash data difficult.

Speed Data Collection and Analysis

The main goal of this study was to determine the effectiveness of the beacons. One way to measure beacon effectiveness was to investigate the effect of the flashing beacons on driver speeds. To evaluate this, speeds for every vehicle were captured between September 13, 2007 and April 30, 2008.

Speeds were captured at two different locations, one of which was inside the Highway 140 ice zone (milepost 21.7 to 41.7) and the other outside the ice zone. The outside zone speeds were measured via an ODOT automated traffic recorder (ATR) located at milepost 16, approximately 5 miles west of the western boundary of the ice zone. The ATR consists of two inductive loop detectors in series and a roadside data collector. Hourly average speeds in each direction were obtained from the ATR and used in the data analysis.

Speeds inside the ice zone were collected via a temporary speed measurement device that was installed at the RWIS station at milepost 35 near the summit of the pass where winter road conditions tend to be most severe. The device was a Wavetronix SmartSensor HD which uses a dual radar screen to determine vehicle speeds. Hourly average speeds in both eastbound and westbound directions were calculated from the vehicle speeds collected by the Wavetronix unit.

ODOT maintains a database on the status of the flashing beacons signs at either end of the ice zone. Hourly beacon status data were collected from this database and matched with the hourly average speeds at the ATR and RWIS sites. The final data set consists of 19,838 hourly average speeds matched with driving direction, site location, and beacon status. These data are summarized in Table 2.

The purpose of the beacons is to warn drivers that the roads might be icy. It was therefore theorized that the driving speeds would be lower when the beacons were flashing. To rule out effects based on driving direction and speed capture site, a full factorial analysis was conducted. With direction, site, and beacon status as factors that might affect speed, a three way analysis of variance was conducted.

The results revealed that overall speeds were significantly ($F(1,19830)=3765$, $p<.01$) lower when the beacons were flashing. This was true for both eastbound ($t(9954)=39.31$, $p<.01$) and westbound ($t(9880)=35.25$, $p<.01$) directions and for both the ATR ($t(10886)=22.54$, $p<.01$) and RWIS ($t(8948)=52.87$, $p<.01$) speed capture sites.

At the RWIS site specifically, average speeds dropped by 9.5 mph overall, 10.4 mph for those traveling eastbound, and 8.4 mph for those traveling westbound when the beacons were flashing. Further analyses revealed significantly lower speeds when beacons were flashing under all scenarios (comparing only westbound travelers at the RWIS site for example). While these results seem to support the theory that flashing beacons result in lower speeds, care must be taken when assuming causality. It cannot be determined from these data if the beacons caused the drivers to slow down or if the poor road conditions that caused the beacons to flash also caused the drivers to slow down. All that can be reasonably assumed is that there is a statistically significant relationship between the flashing beacons and lower driving speeds. To truly establish causality between beacon status and driving speeds would require additional studies of speed data under the control scenario where beacons are not flashing despite poor weather conditions – these types of studies could place drivers at additional risk and are not recommended.

The analyses also revealed that overall speeds were significantly ($F(1,19830)=5198$, $p<.01$) lower at the RWIS site than at the ATR site. Additional analyses of each contributing factor (e.g. beacons on) or combination thereof (e.g. beacons off and traveling westbound) revealed that this was always the case. Icy roads or not, uphill or down, speeds are consistently, significantly higher at the ATR site than the RWIS site.

The factorial analysis also revealed a significant ($F(1,19830)=1635$, $p<.01$) interaction effect between beacon status and speed capture site. What this means is, not only are the speeds lower at the RWIS site when the beacons are on (i.e. the main effects described in the preceding two paragraphs) but that the spread between speeds at the RWIS and ATR sites is significantly higher when the beacons are on.

Table 2 Speed Data Summary Statistics

Dependent Variable: Speed

Beacon Status	Direction	Location of Speed Capture	Mean	Std. Deviation	N
Off	West Bound	ATR	59.8749	4.4218	2501
		RWIS	57.5067	6.3832	1729
		Total	58.9069	5.4372	4230
	East Bound	ATR	61.9494	3.1289	2559
		RWIS	58.4437	5.8878	1809
		Total	60.4975	4.8031	4368
	Total	ATR	60.9241	3.9608	5060
		RWIS	57.9858	6.1519	3538
		Total	59.7150	5.1859	8598
On	West Bound	ATR	57.7643	5.3767	2911
		RWIS	49.0881	9.2677	2741
		Total	53.5567	8.6797	5652
	East Bound	ATR	60.1783	4.1001	2917
		RWIS	47.9741	9.4876	2671
		Total	54.3448	9.4320	5588
	Total	ATR	58.9725	4.9302	5828
		RWIS	48.5383	9.3926	5412
		Total	53.9485	9.0697	11240
Total	West Bound	ATR	58.7396	5.0683	5412
		RWIS	*52.3444	9.2320	4470
		Total	55.8468	7.9213	9882
	East Bound	ATR	61.0060	3.7827	5476
		RWIS	*52.2016	9.6978	4480
		Total	57.0442	8.3289	9956
	Total	ATR	59.8795	4.6095	10888
		RWIS	52.2730	9.4677	8950
		Total	56.4478	8.1502	19838

*Indicates a non-significant difference

A similar speed analysis was conducted using road condition information from ODOT's Computer Aided Dispatch (CAD) system. The CAD reports include a road surface condition which is updated periodically by ODOT's maintenance crews. Using this information, speeds from the ATR and the RWIS sites obtained while the beacons were flashing were evaluated under "packed snow" conditions. As expected, when packed snow conditions were observed, mean speeds at the RWIS location (43.4 mph) were significantly less than those measured at the ATR location (57.4 mph). Even when there was not packed snow, mean speeds at the RWIS location (52.6 mph) were significantly less ($t(6140)=51.5$, $p<.01$) than mean speeds at the ATR location (60.4 mph) when the beacons were flashing. While both speed decreases are statistically significant, the magnitude of reduction is clearly smaller when packed snow was not present at the pass. Also notable is that the RWIS mean speed under non-packed snow conditions (52.6 mph) is near the 55 mph posted speed.

Finally, direction of travel was compared to overall speeds and the data reveal that speeds for westbound travelers were significantly ($F(1,19830)=135$, $p<.01$) lower that speeds of eastbound travelers. The same was true for every factor and combination of factors except one: there was no significant difference ($t(8948)=0.713$, $p=.476$) in eastbound and westbound speeds at the RWIS site when the factor of beacon status is ignored. The mean speeds compared in this relationship are marked with an * in Table 2. In every other case, those traveling east are going faster than those traveling west. This may be because westbound travelers are usually departing from a basin where the weather is more often inclement than those traveling eastbound from a valley where the weather is usually milder. Thus, those leaving the climatologically harsher basin may be more prepared for icy roads and drive accordingly.

These analyses of the speed data illustrated two important relationships.

First, and most importantly, speeds are significantly reduced when the beacons are on: this is especially true within the ice zone.

Secondly, and somewhat unexpectedly, the data reveal that speeds are lower at the summit than on the west side of the pass even when the roads are warm and dry. The reason for this is unknown but could be related to roadway geometry and the numerous recreational access points (such as sno-parks) in the summit region. Also unexpectedly, the data suggest that westbound speeds are consistently lower than eastbound, perhaps because the westbound drivers are traveling from a harsher climate whereas the eastbound drivers begin their trip in a milder climate.

Driver Surveys

Another essential part of the project was to determine if drivers were aware of the beacons and, if so, how the beacons affected their driving habits. This was accomplished through in-person surveys administered to three different populations. The first surveys were conducted within the ice zone on Highway 140 during very poor weather and road conditions. Survey respondents included a number of people who were participating in winter sports at the sno-parks, drivers who were using the rest stop at the sno-park while crossing the pass, and drivers who were putting on tire chains in preparation for crossing the pass. In total, 45 on-site surveys were conducted within the ice zone.

The second set of surveys was administered online to students, faculty, and staff at the Oregon Institute of Technology (OIT) in Klamath Falls. Approximately 2,500 people received a general invitation to fill out the survey and 59 people responded, yielding a response rate of 2.4 percent.

The final surveys were mailed out to a sample of residents chosen randomly from a phone book for Klamath Falls and surrounding areas. Out of the 661 people who were sent the survey, 105 completed and returned it, giving a response rate of 15.9 percent.

The survey began with demographic questions relating to where the drivers live, what type of vehicles they were driving, how often they drove the pass, their frequency of travel and their tendency to drive the pass in the winter.

The survey went on to ask questions about the beacons, beginning by querying whether the drivers were aware of the beacons. Out of 209 respondents, 186 responded that they were aware of the beacons. The fact that nearly 90 percent of those surveyed responded that they were aware of the beacons strongly suggests that the beacons are of sufficient size and height as to be visible to a vast majority of the population.

Drivers were then asked a series of questions to gauge their level of confidence in the beacons—to determine if *seeing is believing* so to speak. The results of these questions are summarized in Table 3. The first question asked them to rate their confidence in the beacons. As shown in Table 3, of those who reported being aware of the beacons, only 9.4 percent of the respondents expressed no confidence in the beacons and nearly 50 percent reported being very or extremely confident in the beacon. To evaluate confidence in another way, drivers were asked if they ever experienced a situation when the beacons were flashing but the roads were not icy: a false positive. The results reveal that many, 37.3 percent, do not recall one way or the other. Of those who did recall, approximately 45 percent recorded experiencing a false positive. A similar question was asked regarding false negatives—situations when the sign was not flashing but the roads were icy. These results were similar, with 40 percent of the respondents not remembering one way or the other and 35 percent of the remainder recalling an experience of a false positive.

It should be noted that these results do not suggest that false positives or negatives actually took place, the survey data are merely used to assess driver perceptions, and the perceptions are that false positives and negatives do take place somewhat frequently. This does not, however, seem to affect driver confidence to any great extent as the drivers' confidence in the beacons remain rather high.

Table 3 Beacon Confidence Measures

		Freqeuncy	Percent
Driver Confidence in Beacons	Extremely Confident	19	**10.5**
	Very Confident	68	**37.6**
	Somewhat Confident	77	**42.5**
	Not at all Confident	17	**9.4**
False Positives	Yes	50	**28.2**
	No	61	**34.5**
	Do Not Recall	66	**37.3**
False Negatives	Yes	36	**20.7**
	No	68	**39.1**
	Do Not Recall	70	**40.2**

Another set of questions asked drivers to rate the degree to which the beacons, when flashing, affected their speed, attention, and caution. The results of these questions are summarized in Table 4. It is reassuring that no one reported being less cautious or attentive or reported increasing their speed to any degree when the lights were on. In fact, the vast majority of the respondents reported being a least somewhat more cautious (88.4%) and attentive (85.8%) and driving somewhat slower (87.7%) when the beacons were flashing. The results are very encouraging and suggest that beacons are fulfilling their intended purpose.

Table 4 Effects of Flashing Beacons on Drivers

		Freqeuncy	Percent
Effect on Speed	Much Slower	56	**31.3**
	Somewhat Slower	101	**56.4**
	Same	20	**11.2**
Effect on Attention	Much More Attentive	71	**40.3**
	Somewhat More Attentive	80	**45.5**
	No Change	24	**13.6**
Effect on Caution	Much More Cautious	67	**39.0**
	Somewhat More Cautious	85	**49.4**
	No Change	19	**11.0**

Another set of questions asked drivers to rate different sources of information as to how they affected their judgment of the road conditions on a Likert-type scale of 1 to 5 with 1 being the most important source of information and 5 being the least. The data are summarized and described in Table 5. These data reveal that the drivers rely most on their own judgments of weather and road conditions. Following their own judgments, drivers reported relying on the warning beacons. The fourth most important source of information is broadcast or online sources. Vehicle temperature display was reported to be the least important source of information, though the bimodal nature of the distribution suggests that some of the drivers likely drive vehicles without temperature displays. As intelligent transportation systems represent relatively new technologies, it is not surprising that drivers still prefer to rely on their own judgments of road conditions. However, out of the three types of technologies presented to drivers in the surveys, the beacons were rated as most important. This finding further suggests that the beacons are having an impact on drivers and fulfilling their intended purpose.

Table 5 Rankings of Information Sources for Road Condition Judgments

	Ranking (1=Most Important, 5=Least Important)							
	1	2	3	4	5	Mean (St. Dev)	Mode	Median
Outdoor Weather Conditions	119	30	10	3	1	**1.39 (0.74)**	**1**	**1**
Flashing Beacons	23	49	43	35	18	**2.86 (1.21)**	**2**	**3**
Broadcast/Online Sources	21	41	45	31	27	**3.01 (1.27)**	**3**	**3**
Visual Judgement of Road Condition	84	39	23	16	5	**1.92 (1.41)**	**1**	**1**
Vehicle's Onboard Temperature Display	27	32	27	17	58	**3.29 (1.53)**	**5**	**3**

The survey also asked the following question: "When the roads at the beacon location are clear and dry but the beacons are flashing, what distance do you assume you will have to travel prior to reaching icy roads?" This question might be useful in determining sign placement of future projects. The results shown in Table 6 reveal that 68.5 percent of the respondents assumed that icy roads would be encountered with 2 miles of the beacons. While the actual distance from beacons to icy roads varies considerably throughout the season, the beacons are located at significantly lower elevations than the pass and anecdotal evidence suggests there are many days when the road conditions are dry and clear at the beacons and several miles must be traveled before encountering ice on the road.

Table 6 Perceived Distance from Beacons to Ice

		Freqeuncy	Percent
Distance from Beacons to Ice	Less Than 1 Mile	58	**32.0**
	1 to 2 Miles	66	**36.5**
	3 to 5 Miles	40	**22.1**
	6 to 10 Miles	18	**9.9**
	10 to 20 Miles	7	**3.9**

Finally, survey participants were queried about how beacon effectiveness could be improved. Five choices were presented along with an 'other' category for open-ended responses. On this question, respondents could check as many of the boxes as they wanted—including, if they thought that the beacons worked just fine, none. The data are summarized in Table 7. While many of the open-ended responses say that the system works just fine, some reasonable suggestions were made such as putting beacons on both sides of the roads and making them bigger and higher. Others suggested more advanced systems that could display road temperature, degree of danger, or more detailed descriptions of where exactly the ice was located.

Table 7 Driver Suggestions on Ways to Improve Beacon Effectiveness

		Frequency	Percent
Suggestions to Improve Beacon Effectiveness	Make Beacons More Visible	36	**17.3**
	Include More Beacons	58	**27.9**
	Include More Signs	22	**10.6**
	Move Beacons Closer to the Pass	30	**14.4**
	Ensure Beacons are more Accurate	60	**28.9**
	Other	38	**18.3**

The purpose of the survey was really twofold: to determine if drivers were aware of the beacons and to determine if the beacons had an effect on driving habits. The results reveal that an overwhelming majority of the population is aware of the beacons. The results also suggest that people are confident in the beacons, even if they think that the beacons are not always reliable. Finally, and most importantly, drivers reported slowing down and being more cautious and attentive when the beacons are flashing. This evidence seems to support the idea that the beacons are serving their intended purpose and acting in the best interest of all who drive on Highway 140 during the winter.

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