Use of Real Time Weather Variables to Operate Rural Interstates in Wyoming

R.K. Young [1]

[1] University of Wyoming
Laramie, WY, USA

Corresponding author's E-mail: rkyoung@uwyo.edu

ABSTRACT

The State of Wyoming experiences severe weather conditions including strong winds and fast moving, winter weather events that create significant safety hazards for travellers. The Wyoming Department of Transportation (WYDOT) views the use of Intelligent Transportation System (ITS) applications as promising methods for improving safety along these roadways. The roadways selected for ITS deployment are rural roadways with limited services and long distances between travel decision points. The primary purpose of these applications are to increase roadway safety by providing better real time weather information and through weather responsive roadway operations. Recent ITS projects utilize real-time weather data to help operate the ITS components along segments particularly hazardous rural interstate segments to help determine DMS message sets, set variable speed limits, and to warn commercial vehicles of hazardous wind conditions. Another current project is also investigating the use of real time data to develop a road condition travel index system to better inform travellers of the current roadway conditions.

Keywords: Variable Speed Limits, Travel Times, RWIS

1 INTRODUCTION

Weather events in the State of Wyoming frequently impact the roadways throughout the state and range from heavy snowfall storms, blowing snow, and strong wind conditions during clear weather. Storm events are often fast moving and severe and cause significant safety and operational impact on the state's road system. The rural nature of the state compounds the problem since there are long stretches of roadway with few or no services resulting in few decision points for travellers determining whether to begin or continue their trip.

Wyoming is crossed by two main interstates: Interstate 80 runs east-west across the southern part of the state and is a major freight corridor connecting the west coast with the eastern and Midwestern portions of the country. On average 50% of the vehicles on I-80 are heavy freight vehicles. Interstate 25 runs north-south across the eastern side of the state and if a major freight corridor connecting the United States to Canada and Mexico and averages 25% freight vehicles. Given the reliance of these corridors by the freight industry there are significant economic impacts when the roads are closed for weather events.

A comprehensive analysis of crash rates along the entire section of I-80 in Wyoming was performed in 2006 by the University of Wyoming [3]. The results indicated that the section of interstate between Laramie and Rawlins experiences some of the highest crash rates in the state. Most of the hazards that drivers experience on these sections are high winds, blowing snow, and icy spots.

To address both the safety and operational impacts of weather events on roadways throughout the state, the Wyoming Department of Transportation (WYDOT) has looked to the use of technology through various Intelligent Transportation System (ITS) applications. In the following sections this paper highlights three ITS applications that have either been implemented or are currently being studied that use real-time weather monitoring to improve safety and operations of rural interstates. The three ITS applications are variable speed limits, high wind warning system, and the travel time based winter travel index.

2 RURAL VARIABLE SPEED LIMIT SYSTEMS

The primary goal of Variable Speed Limit (VSL) systems in Wyoming is to reduce the speed variability between the passenger vehicles and the heavy vehicles in the corridor, which is a common complaint of motorists traveling this corridor. During good weather conditions (low wind speed, no surface moisture, good visibility), speed studies have indicated that the passenger cars are traveling faster than the heavy vehicles. When there is blowing snow along the corridor, the heavy vehicles sit higher off the ground so are not as affected by the ground blizzards as the passenger vehicles. Therefore, the heavy vehicles are often traveling faster than the passenger vehicles during poor road conditions. VSL systems post regulatory speeds that are meant to better represent the actual conditions, which in turn could reduce the amount of variability in the speeds between passenger and heavy vehicles. It is expected that the reduced speed variability would lead to improved safety in the corridor.

As of the 2011-2012 winter season, Wyoming has implemented four VSL corridors along Interstate 80, which runs east-west for over 400 miles along southern portion of the state. A fifth VSL corridor is planned for the 2012-2013 winter season and will be the first VSL in Wyoming installed on a non-interstate, two-lane highway. The first VSL system in Wyoming was installed in the Elk Mountain area between the towns of Laramie and Rawlins. The distance between Laramie and Rawlins is approximately 100 miles and the project corridor is a 52-mile subsection. The original project corridor began at milepost 255 and ended at 275. For the second winter season the corridor was extended to the west to milepost 238 to make the VSL corridor 52 miles in length. The entire corridor is a rural, divided, four-lane interstate. In 2005, the ADT on the corridor was 10,800 vehicles per day and experiences a very high percentage of heavy vehicles. Using vehicle classifications established by the Federal Highway Administration, 60% are heavy vehicles, which include vehicles with three or more axles, 25% are passenger vehicles, 20% are Two-Axle, 4 Tire Single Units, and the remaining percentage is split between motorcycles, buses, and Two-Axle, 6 Tire Single Units.

Figure 1. Picture of Variable Speed Limit Signs

To monitor the corridor and to provide real time data for setting speed limits, the corridor has 14 road weather information systems (RWIS), 12 radar speed sensors, and 8 Pan-Tilt-Zoom (PTZ cameras). The control strategy under development for the VSL corridors uses two parallel algorithms to determine speed limits based on the 85th-percentile of the observed speeds and based on real time weather data. The control strategy than reconciles the results from the two algorithms to recommend the speed. Dampening features in the algorithms prevent small and frequent changes in speed limits yet still allow the system to be responsive to the fast moving winter storm events common to the corridor. The control strategy also uses case-based reasoning to classify storm events and the driver response to previous speed limits to create a self-learning algorithm that defines the control strategy's success for a particular storm event on observed speed compliance and speed variability.

Ultimately the success of the VSL implementation will be based on changes in observed crash rates and the frequency and duration of road closures along the corridor. Evaluation of these performance measures will be based on three years of implementation due to the variability of winter events in the corridor. Anecdotal and qualitative observational information from the first winter led WYDOT to proceed with plans for more corridors. The second VSL corridor was implemented in late winter 2010-2011 in a 22 mile corridor between the cities of Green River and Rock Springs from milepost 88 to milepost 110. The third and fourth VSL corridors were implemented for the 2011-2012 winter season between Laramie and Cheyenne (milepost 317 to 345) and in the corridor east of the city of Evanston through mountainous terrain known as the Three Sisters (milepost 7 to 27).

Currently work is underway to refine the control strategies for the three newer VSL corridors and to investigate the transferability of the algorithms between corridors.

3 HIGH WIND WARNING SYSTEM

In addition to winter weather events involving snow and ice conditions, Wyoming also is subject to frequent and severe high wind conditions. These wind conditions can be associated with snow events causing ground blizzard conditions but can also occur during clear and dry conditions. The state of Wyoming is often windy and during the winter the wind speeds often reach sustained levels of 30 to 40 mph with wind gust speeds of 50 to 60 mph [2]

An analysis of truck crashes due to high winds revealed that the high wind events during clear and dry conditions yielded the highest risk for overturning or sliding truck crashes [4]. This work identified five high risk locations in Wyoming for high wind related truck crashes. A follow up effort on one of these locations led to the development of the high wind warning system described here The results of this effort are described in more detail in a Transportation Research Board Paper from 2010 [1]..

The location of the high wind warning system was selected along Interstate 25, which runs north-south along in the eastern portion of the state. Based on historical truck crash data for the corridor the most hazardous section of the interstate was between milepost 70 and 71 (see Figure 2). The predominate crash type for this location was overturning truck crashes during either high wind or ground blizzard conditions. Figure 2 clearly shows the pronounced risk at this location compared to adjacent sections of the road.

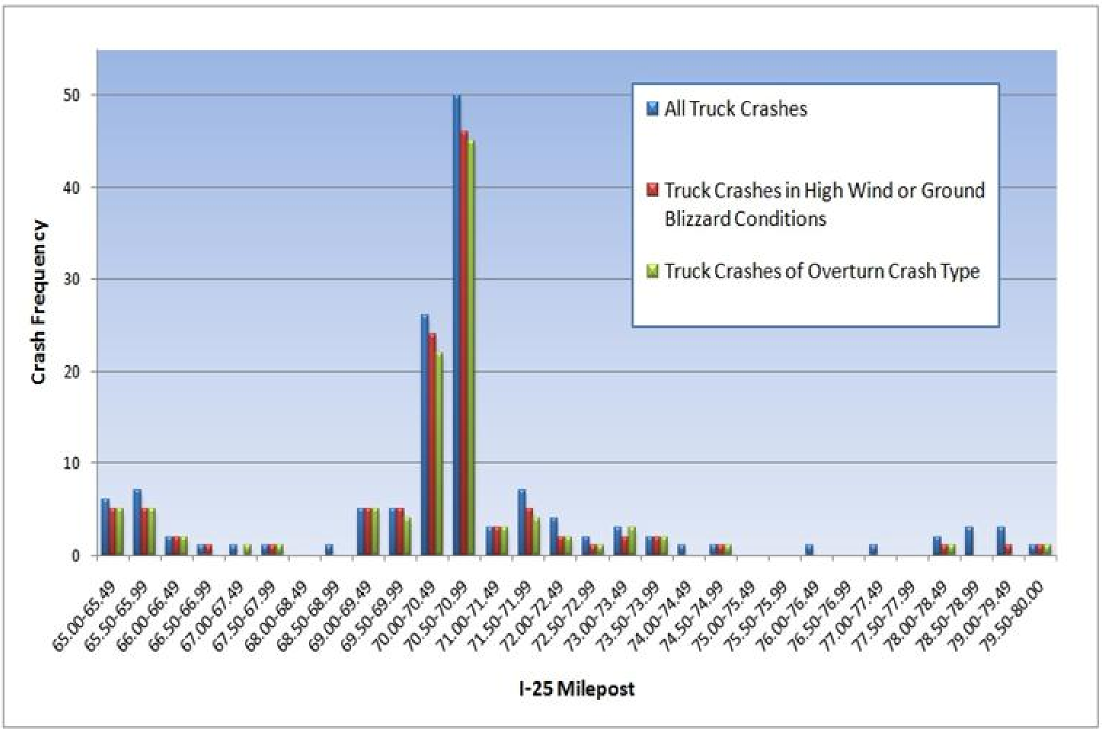

Figure 2. Truck Crashes along Interstate 25by Milepost from 1994 to 2007

The crash records only indicated that the conditions as high wind at the time of the crash and did not provide informaiton of the mesured wind speeds so the crash data was merged with wind speed and wind gust data from a Road Weather Information System located on the corridor. This informaiton was used to develop risk equations related to wind speeds. Figure 32 shows the cummulative frequency graph of wind speeds at the time of the crash.

The main objective the high wind warning system research was to develop a high wind warning system that can be used by WYDOT to improve the truck safety in high wind conditions near Bordeaux area. The system uses three operational levels to manage the high wind warning system based on how restrictive the system is for a given wind threshold.

- Level 1: Wind speeds and road surface variable thresholds used to implement advisory warning messages
- Level 2: Wind speed, road surface variable, vehicle type and vehicle weight thresholds to determine road closure **only** for high-profile, light-weight vehicles.
- Level 3: Wind speed, road surface variable and vehicle type variable thresholds to determine road closure for **all** high-profile vehicles.

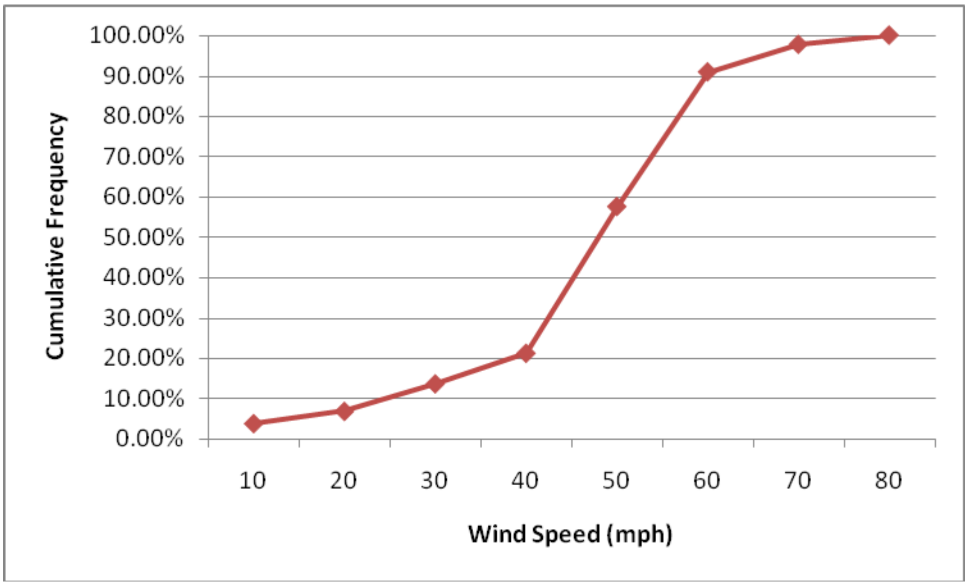

Figure 3. Cumulative Crash Frequncy of Wind Speed When Crash Occurred

Level 1 uses basic ITS technology of RWIS, DMS, CB Wizard, Traveller Information System and Highway Advisory Radio (HAR). RWIS is used to collect and record the weather data such as wind speed, wind gust speed, wind directions and road surface conditions; the remaining technology is used to broadcast the warning messages to travellers.

The determination of threshold conditions to trigger warning messages needs to consider many factors. On one hand, the wind speeds cut-off cannot be too high otherwise the warning may not adequately warn travelers of potential hazards. On the other hand, the wind speed cut-off cannot be too conservative otherwise the warning messages will be triggered too frequently leading to the potential of messages being disregarded. As seen in Figure 2, the average wind speeds when the crashes occurred is 47 mph. If 47 mph is chosen as the advisory warning cut-off, approximately half of the crashes would occur when the advisory warning messages (Level 1) were not triggered. Therefore, to be conservative, a lower 30 mph is recommended as the initial threshold for Level 1. A 30 mph threshold represents is the 15% wind speed during the crash occurrence, which means that 85% of the historical crashes would have occurred when the hazard system is active.

To verify the frequency of advisory wind warning triggered, the wind speeds frequency during the 2008 to 2009 winter season (November 1st, 2008 to April 30th, 2009) was analysed against proposed wind speed thresholds (Table 1). The RWIS tower collects weather information at 10-minutes interval, and there are 35,137 data records collected for the 6-month winter season when high winds are more frequent. If the advisory wind warning cutoff was set as 30 mph, 87.96% of the time would be below this cut-off and 12.04% of the time the warning signs would be activated. This equates to approximately 518 hours of warning message operation. The low value of 12.04% ensures that the warning message does not activate too frequently.

Wind Speeds (mph)	Wind Speed Frequency	Percent	Cumulative
≤10	10,893	31.00%	31.00% (≤10)
>10 and ≤20	11,258	32.04%	63.04% (≤20)
>20 and ≤30	8,756	24.92%	87.96% (≤30)
>30 and ≤35	2,093	5.96%	93.92% (≤35)
>35 and ≤40	1,183	3.36%	97.28% (≤40)
>40 and ≤45	5,34	1.51%	98.80% (≤45)
>45 and ≤50	242	0.69%	99.49% (≤50)
>50 and ≤55	121	0.34%	99.83% (≤55)
>55 and ≤60	54	0.15%	99.99% (≤60)
>60 and ≤65	3	0.00008%	100% (≤65)
Total	35,137	100%	-

Table 1. Wind Speed Frequency during 2008-2009 Winter Season

Level 2 uses the same equipment as Level 1 except adds height detection devices and weigh-in-motion technology. As discussed earlier, low weight or empty vehicles are more vulnerable to the high wind conditions than fully loaded vehicles. Height detection devices would recognize high profile vehicle and weigh-in-motion system is used to estimate lower weight vehicles on the road and transmit warning messages, or even stop them entering the hazardous location.

The average wind speed of the historical overturned crashes for the empty trucks is 34 mph. It is suggested that WYDOT use cutoff 40 mph as the threshold for the warning messages or road closure for the high profile, light weight trucks. In Table 3, the operational time for Level 2 is 2.72%, which equates to 117 hours of operation.

Level 3 uses all the technology of Level 1 plus the addition of height detection devices. Of the 132 crashes, 70 (53%) of them occurred on the same day as another crash. These repeat truck crashes on the same day indicate that the weather is not suitable for large truck driving. The average wind speed when these 70 crashes happened is 51 mph, which is higher than the average value of 132 crashes of 47 mph. Using the same methodology in the Level 1, 15th percentile of wind speed for the 70 crashes is 45 mph. In addition, 45 mph relates to the point where the likelihood of overturn is in the peak in the second order model. Therefore 45 mph is selected as the threshold to close corridor to all vehicles classified as large trucks. According to Table 3, the frequency of wind speeds above 45 mph is 1.20%. This equates to approximately 52 hours of road closure for all high profile vehicles.

4 WINTER SEVERITY TRAVEL INDEX

The last effort described briefly here is a research effort that is just beginning that deals with the use of travel times along rural corridors to provide winter road condition information to drivers. While travel times are used frequently in urban areas to convey congestion levels they are not typically used in rural areas. One of the challenges with rural travel times unfamiliarity of drivers along rural interstates with how long the trip would normally take if the road conditions were ideal.

The I-80 Corridor between Cheyenne and Laramie is an ideal corridor as a starting point to research the applicability of applying these techniques to a rural setting since the corridor is already heavily instrumented and there is an advanced traveller information system in place. The research problem will address the applicability of travel time and travel time reliability measures from the perspective of both passenger car and heavy vehicle travellers that are either frequent or first time users of the corridor.

WYDOT's Intelligent Transportation System Program currently utilizes extensive use of speed sensing equipment, most commonly non-invasive side fired radar equipment. This research will investigate the applicability of using speed sensor equipment as well as vehicle monitoring devices such as blue tooth readers to calculate corridor travel times. Bluetooth readers sense devices in vehicles that use Bluetooth communications and read the unique Media Access Controller (MAC) address that these devices have to match up vehicle observations at different points along the roadway. While these MAC addresses are unique to the device they do not contain identification information to the specific vehicle or driver so they are not considered invasive to personal privacy. Travel times will be estimated using each of these device types as well as a combination of both to determine the technology that provides the best travel time estimates.

Early results of travel time distributions for the corridor show bimodal distributions for both directions due to the high percentage of trucks along the corridor with approximately half of the vehicles being freight vehicles (see Figure 4).

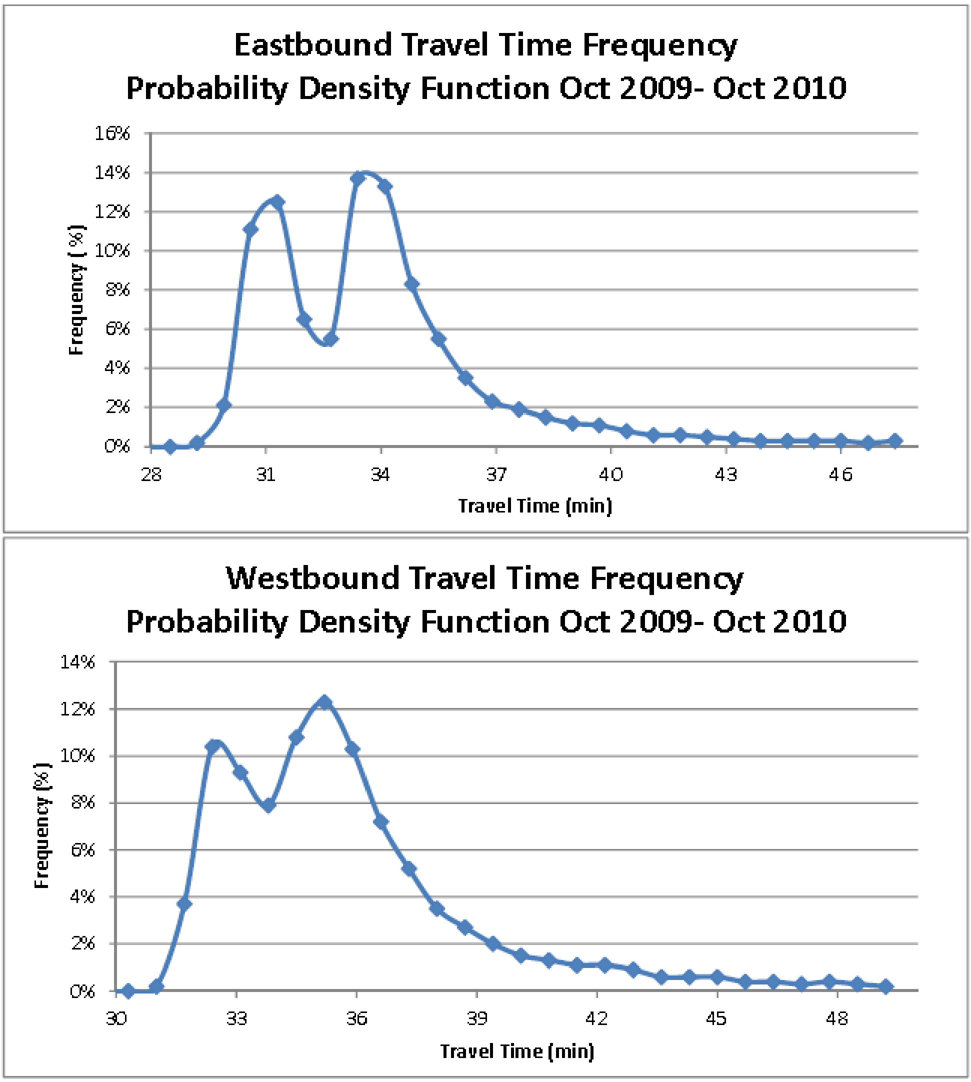

Figure 4. Travel Time Distributions along Interstate 80 between Laramie and Cheyenne

The next step of this research will be to collect travel time data from the Bluetooth readers to compare with the speed sensor based travel times. A road condition index based on travel time reading and RWIS data will be developed and tested with travellers on the corridor to determine the best way to provide road condition information to rural drivers.

5 REFERENCES

[1] Dai, Q., Young.R. "High Wind Warning System to Prevent Overturning Truck Crashes in Wyoming" *Proceedings form the 89th Annual Meeting of the Transportation Research Board*, Washington, D.C., January 2010.
[2] Curtis, J. and K. Grimes. (2004) *Wyoming Climate Atlas*. Office of the Wyoming State Climatologist, Laramie, WY.
[3] Tomasini, M. (2006). *An Investigation into Interstate Highways with Large Percent Trucks*. University of Wyoming Master's Thesis.
[4] Young, R, Liesman, J. 2007. Estimating the relationship between measured wind speed and overturning truck crashes using a binary logit model. Accident Analysis and Prvension. 39: 574-580.

ACKNOWLEGEMENTS

The author would like to thank the Wyoming Department of Transportation and the Mountain-Plains Consortium for funding the research described in this abstract.