APPLICATION OF ITS IN RURAL AREAS
Variable Speed Limit System on I-80 in Southeastern Wyoming

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Table of Contents

Table of Tables

Table of Figures

ABSTRACT

This paper evaluates the effectiveness of a recently implemented Variable Speed Limit (VSL) system in Elk Mountain corridor between Laramie and Rawlins in southeastern Wyoming. The data collected from different Intelligent Transportation System (ITS) components (speed sensors, Road Weather Information System (RWIS) and Dynamic Message Sign Event Database (DMS) are merged and analyzed to evaluate the effectiveness of posted speed limit reductions on reducing speeds in the corridor during hazardous weather events. The speed observations are categorized by vehicle type (passenger cars or heavy trucks) and average speed, speed variance and speed compliance were analyzed. Findings suggest the necessity of an automatic control strategy system to replace the current manual protocol currently.

INTRODUCTION

Weather conditions in Wyoming are often unpredictable and frequently changing, so road users must choose safe driving speed based on what they think that is suitable for the current road conditions. This can lead high speed variance among the vehicles, particularly between passenger cars and trucks, which lead to increased vehicle crashes.

A speed limit sign helps the users of the roadway to choose the appropriate speeds drivable on the road under ideal conditions. As speed limit signs are typically static the posted speeds may become too high for changing weather and traffic conditions. Variable Speed Limits (VSL) are a type of Intelligent Transportation System (ITS) that allows for quick response to changing conditions by adjusting the posted speed limits to ones which are at safe level for those conditions.

BACKGROUND AND LITERATURE REVIEW

The main purpose of setting speed limits is to provide a safe and smooth flow on a roadway. The posted legal limit informs motorists of maximum driving speeds that decision makers consider reasonable and safe for a road class or highway section under favorable conditions (Board, 1998).

Variable Speed Limit systems comprise of dynamic message signs (DMS) that are installed along a roadway which are connected to Traffic Management Center (TMC) are used to display advisory speed limits. VSL system enables transportation system managers to dynamically post a speed limit that is appropriate for current traffic, weather, or other conditions.

VSL systems have been around for the last 30 years and currently are successfully being used in parts of Europe and Australia. These systems are being used in several states and could be implemented in appropriate areas across the united states to help potentially reduce errors caused by drivers in selecting speeds and to enhance safety of roadways through the use of advanced technology (Zarean, Pisano, Dirnberger, & Robinson, 1999).

Washington State has introduced VSL to improve road safety and to increase the availability of road condition and weather information to the road users.

The project location is I-90 Snoqualmie Pass (Rural Area), tests were conducted on a roadway of length of 17 miles (Mile Post (MP) 45 to Mile Post (MP) 62) during winter months, 6 weather stations were used to provide environmental conditions and the sensors in the pavement are used to determine pavement conditions. Using all this information WSDOT has developed a matrix of speeds which included visibility. When the road conditions are poor speed limits were reduced in 10 mph increments, the decision to reduce the speed limit is based on feedback from state patrol and snow plow operators. *WSDOT has observed motorists slowing down when the VSL system is in use* (Zarean, Pisano, Dirnberger, & Robinson, 1999).

Germany applied VSL to stabilize traffic flow even under heavy flow conditions, thus reducing crash probability, improving driver comfort and reducing environmental impacts.

The project location is on rural expressways, A8 between Salzburg and Munich, A3 between Sieburg and Cologne, A5 near Karlsruhe, test section is of length 18.7 miles and VSL signs are located every 1.2 miles. The safe logical speed was determined by a computer algorithm based on information gathered from inductive loops and other weather detectors. The German Ministry of Transport has seen some safety benefits from the use of VSL. *Motorists respond better to the electronic signage than the fixed signage, because the electronic signs provide advisory information* (Zarean, Pisano, Dirnberger, & Robinson, 1999)

OBJECTIVES

The objective of this paper is to assess the effectiveness of the current VSL system during the storm events by analyzing the data for speed compliance. The larger context for this study is design and deployment of a feasible VSL system on I-80 Elk Mountain corridor in southern Wyoming, and doing so requires more precise models of speed compliance than currently available in the literature.

METHODOLOGY

PROJECT LOCATION

The ITS application of this project is in Elk Mountain corridor which is in southeastern Wyoming on I-80 between Laramie and Rawlins, Wyoming. The project corridor length is 52 miles, starting at 28 miles east of Rawlins and ending at 20 miles of west of Laramie. The Elk Mountain corridor is a rural, divided, four lane interstate and has high percentage of truck volumes (truck percentages range from 50 to 70% trucks depending on the season).

The current VSL system is manually operated, state highway patrol decides the appropriate speed levels which are to be displayed on DMS based on their experience.

DATA SOURCES

ITS components on the project corridor are:

- One Road Weather Information System (RWIS).
- Two Dynamic Message Signs (DMSs) that is located at either end of the corridor (MP 234.6 and MP 311.1).

- Ten speed sensors [Wavetronix SmartSensorHD] have been placed along the corridor that collects data for all four lanes of traffic at each location.
- Twenty dual film scrolling variable speed limit signs located at ten locations, five in the eastbound direction and five in the westbound direction.

Road Weather Information System is located at MP 272 on the project corridor next to the Arlington Interchange. The data collected from this system is for every five minute interval. The data collected provides the information about the pavement and environment conditions on the project corridor. The key RWIS variables are explained below:

- Visibility: The average distance that the driver can see along the corridor in feet.
- Wind Direction: The average wind direction over the five minutes which are classified into eight directions (*N, NE, E, SE, S, SW, W,* and *NW*).
- SfStatus: This variable describes the surface status of the pavement which could be one of these dry, trace moisture, wet, chemically wet, ice, ice warning, ice watch, or error.
- Average Wind Speed: The average wind speed in miles per hour during every five minutes.

Speed Sensors use side fired radar along the road to measure traffic volume, vehicle speed, average speed, direction, lane ID and length based vehicle classification across all four lanes of the interstate. In most cases the speed sensors report average data in 15 minute bins. In order to analyze cars and trucks separately the sensors were taken offline from the speed mapping software and set to log individual observations.

Information about posted speed limit is collected from the Dynamic Message Sign (DMS) event log maintained by Wyoming Department of Transportation (WYDOT). The yellow beacons installed on top of the sign they are activated when the speed limits are reduced.

The data collected from three different sources RWIS, Speed Sensors, and DMS underwent data quality checks before merging into single database. Records with unreasonable or missing were removed from the database. The classification of vehicle is done based on the length of the vehicle; the speed sensor determines the classification of the vehicle into one of eight vehicle categories. For the purpose of this analyses any vehicle greater than 20 feet in length was classified as a truck and any vehicle less than 20 feet was classified as a passenger vehicle.

The resulting database was individual speed observations merged with posted and weather variables.

DATA ANALYSIS

Data analysis was done for the three winter storm events that occurred during December 1 -2, 2009, February 3-4, 2010, and March 18 -21, 2010.

For the storm event December 1 -2, 2009: Variable Speed Limit System Deployed and the data were collected from the following Mileposts, which are located at both ends of the corridor and at a location roughly in the middle.

- Milepost 256.2
- Milepost 273.1

- Milepost 289.5

Four different types of analyses are discussed in this paper:

1. Average speeds from individual vehicle observations for passenger cars and trucks.
2. Standard deviation of speeds from individual vehicle observations for passenger cars and trucks.
3. Further analyses of standard deviation and speeds.
4. Speed compliance for passenger cars and trucks.

Each of these analyses will be explained in the following sections.

Average Speeds from Individual Vehicle Observations for Passenger Cars and Trucks:

The VSL system was deployed on December 1-2 2009 in response to a winter storm and individual observations were collected at MP 256.2, MP 273.1 and MP 289.5. The data were divided into two five minute and fifteen minute averages. Figure 1 graphs the results from MP 256.2. The maximum speed limit on the corridor during the winter months is 65 mph. For this storm the Eastbound and Westbound posted speeds were reduced to 55 mph at the same time and were kept at 55 for approximately 18 hours.

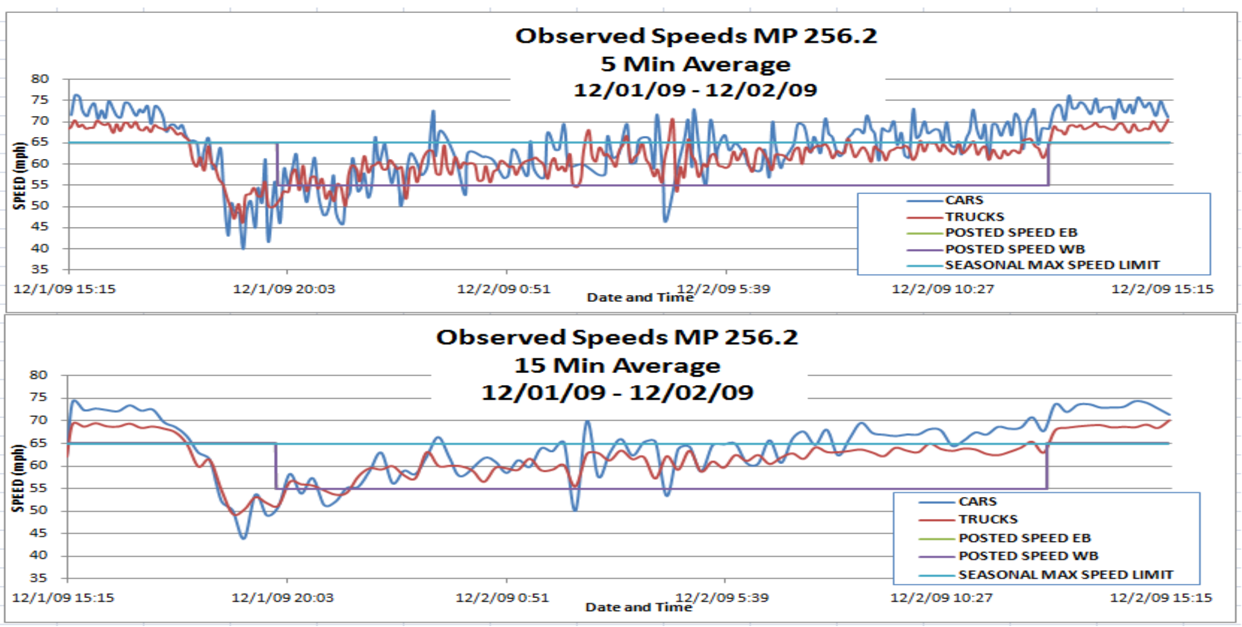

Figure 1 : 5 minute and 15 minute Average Speeds at MP 256.2

From figure 1 it is observed that under ideal conditions car speeds were higher than truck speeds. As conditions decline the car and truck speeds equalize and in some cases the trucks travel at slightly higher speeds. Same trend has been observed at all mileposts for the three storm events.

Standard Deviation of Speeds from Individual Vehicle Observations

Standard Deviation is a measure of the speed variance between vehicles. From the data collected standard deviations were calculated for every 15 minute period. This analysis gives the information about the behavior of two different types of vehicles (Passenger Cars and Trucks).

Figure 2 shows how the speed is varying between cars and trucks. The two vertical lines in the graph denote VSL start and stop points. The duration between them is time for which the VSL is been implemented. No significant difference in speed variations is observed during this period but at MP 289.5 the speed variance among trucks for all the three events a consistent low speed variance was observed.

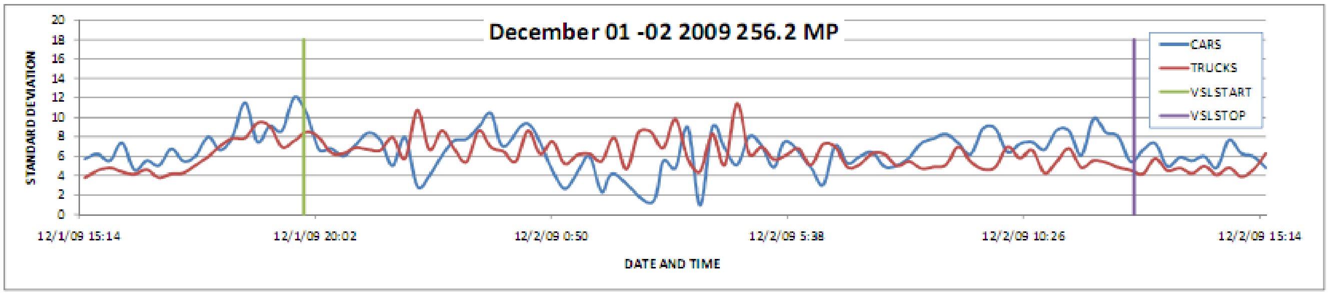

Figure 2: Standard Deviation at MP 256.2

Further Analyses of Standard Deviation and Speeds:

For the December 1-2 Strom event the standard deviations and the speeds were further analyzed by categorizing the observations into four periods:

- Ideal: Observations prior to the storm event based on RWIS data.
- Transitional: Observations in the transitional period where RWIS data indicates worsening conditions but the variable speed limit not yet deployed.
- Initial: Observations in the initial period of the VSL deployment.
- Extended: Observations in the extended period of VSL deployment where speeds are starting to increase but the VSL speeds remain lowered.

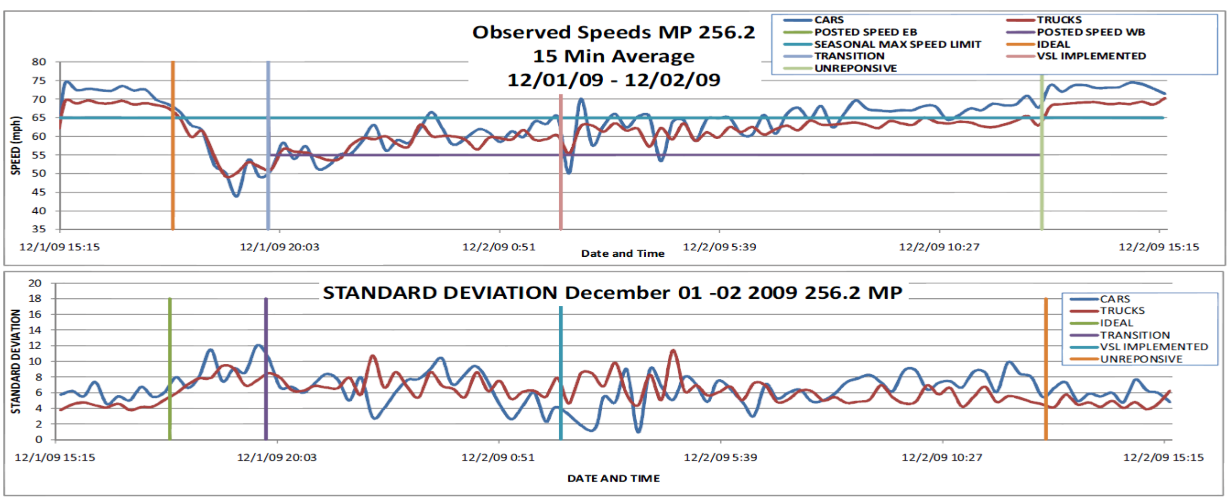

Figure 3: 15 Min average speed and Standard Deviation at MP 256.2

For each of these time periods the average speed, 85th percentile speed, and standard deviations are calculated and summarized in a Table 1 for the three mileposts.

For MP 256.2 the standard deviations follow the expected pattern in that they are lowest during ideal conditions and the highest during the transitional period. Implementation of the VSL appears to reduce the speed variation. At MP 273.1 and 289.5 during the transitional period same trend of increasing speed variance is observed and reached its peak during the VSL implementation period and it is also observed that the variance among cars is more than that of trucks during this period. The same trend followed for all the three winter storm events.

Speed Compliance for Passenger Cars and Trucks.

Speed compliance was defined for this analysis in two ways. The first way a strict definition that determined the percentage of vehicles that were observed going at or below the posted speed limit. The second was a more lenient definition where vehicles were considered compliant if they were going not more than 5 mph above the speed limit. The speed compliance value was calculated for the same four periods as the previous analysis (ideal, transitional, initial speed reduction, and extended speed reduction) for all three speed sensor locations. The percent of vehicles travelling well over the posted speed (>10 mph) was also calculated.

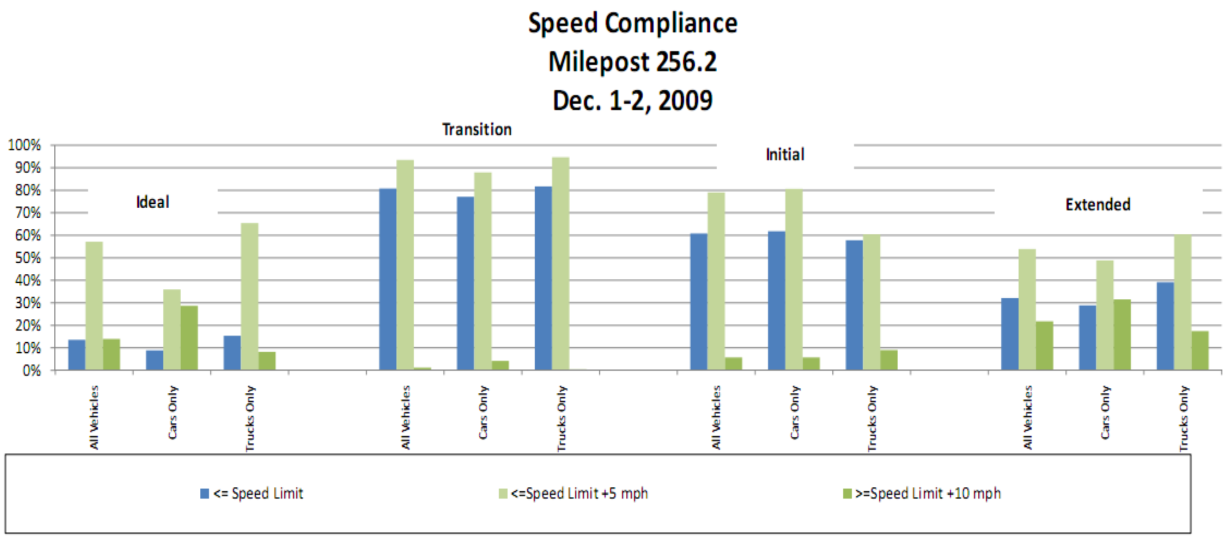

Figure 4: Speed Compliance at MP 256.2

Speed Compliance Rates during the storm event December 1-2, 2009 were shown in a Table 2 and Figure 4.

From the figure 4 it is observed that during transition period there is highest rate of compliance. Strict speed compliance was relatively low for the ideal period before the storm and ranged from 13% to 27% for all vehicles. At all locations, trucks had a high rate of compliance than of cars. Using more lenient definition of compliance the rates for the ideal period increased to 57% to 66% with trucks still having a higher rate of compliance. There were low compliance rates at MP 273.1 which indicate that section of road was not as affected as the other sections. For all the mileposts speed compliance during initial reduction period is higher than ideal period but lower than transitional period.

GENERAL OBSERVATIONS

From all the four analysis the observations made are as follows:

- Speed compliance for both cars and trucks appears to be good at the initial implementation of lower speeds but steady increase in average speeds over time even though the posted speed is not rose indicating that conditions are likely improving but speed limits are not being raised.
- During weather storms the standard deviations of cars can be quite high.
- It is observed that during the transitional period the speed variance between vehicles are increasing which implies drivers are unable to adjust the speeds with respective conditions.
- Speed compliance during speed reduction period have much lower compliance rates than initial speed reduction period and likely indicate that the speed limits are not increasing according to the conditions.

Most importantly from the standpoint of future VSL implementation, compliance with posted speed limits is high, a fact which will be highly useful in determining the optimal control strategy in future research.

FUTURE WORK

All the four analysis will be tested for statistical significance.

In order to overcome this inefficiency in deciding and deploying speed limits a decision support system is being developed. The factors which are influencing the most on average speeds are to be determined using statistical analysis from which an algorithm is to be designed to deploy control strategy. From this control strategy system TMC staff can lower the speed limits according to the weather conditions.

CARS	IDEAL	TRANSITION	VSL IMPLEMENTED	EXTENDED VSL
DURATION	12/1/2009 3:14:52 PM TO 12/1/2009 5:43:36 PM	12/1/2009 5:44:57 PM TO 12/1/2009 7:49:49 PM	12/1/2009 7:50:51 PM TO 12/2/2009 2:12:48 AM	12/2/2009 2:29:59 AM TO 12/2/2009 12:41:56 PM
# OBSERVATIONS	384	166	191	710
AVG SPEED	72.274	56.236	57.268	66.776
85th % SPEED	78.455	68.055	64.45	74.865
STD DEVIATION	5.985	11.671	7.696	7.592

TRUCKS	IDEAL	TRANSITION	VSL IMPLEMENTED	EXTENDED VSL
DURATION	12/1/2009 3:14:52 PM TO 12/1/2009 5:43:36 PM	12/1/2009 5:44:57 PM TO 12/1/2009 7:49:49 PM	12/1/2009 7:50:51 PM TO 12/2/2009 2:12:48 AM	12/2/2009 2:29:59 AM TO 12/2/2009 12:41:56 PM
# OBSERVATIONS	983	677	1205	2843
AVG SPEED	68.845	56.042	57.768	62.884
85th % SPEED	73.17	66.21	64.3	68.4
STD DEVIATION	4.402	9.507	7.478	6.002

Calculations based on 15 minute Average Speeds

Table 1: Observations under Ideal, Transition, Initial and Extended period of VSL deployment at MP 256.2

Speed Compliance Rates During December 1-2, 2009 Storm Event

	MILEPOST 256.2			MILEPOST 273.1			MILEPOST 289.5		
	% AT OR BELOW POSTED SPEED	% AT OR BELOW POSTED SPEED +5MPH	% AT OR ABOVE POSTED SPEED +10MPH	% AT OR BELOW POSTED SPEED	% AT OR BELOW POSTED SPEED +5MPH	% AT OR ABOVE POSTED SPEED +10MPH	% AT OR BELOW POSTED SPEED	% AT OR BELOW POSTED SPEED +5MPH	% AT OR ABOVE POSTED SPEED +10MPH
IDEAL PERIOD									
All Vehicles	13.5%	57.1%	14.0%	25.4%	62.4%	12.8%	27.2%	66.2%	12.7%
Cars Only	8.9%	35.9%	28.6%	14.1%	50.5%	23.4%	12.5%	41.2%	29.1%
Trucks Only	15.4%	65.4%	8.2%	31.2%	69.6%	8.5%	34.0%	77.6%	5.2%
TRANSITION PERIOD									
All Vehicles	80.8%	93.5%	1.2%	68.4%	91.3%	1.0%	83.7%	96.1%	1.1%
Cars Only	77.1%	88.0%	4.2%	66.0%	84.0%	4.0%	83.3%	97.6%	1.2%
Trucks Only	81.7%	94.7%	0.4%	71.5%	96.7%	0.0%	84.4%	96.6%	1.1%
INITIAL REDUCED SPEED									
All Vehicles	60.8%	79.0%	5.8%	55.4%	78.8%	6.1%	36.7%	64.1%	13.3%
Cars Only	61.8%	80.6%	5.8%	60.7%	80.3%	7.4%	38.8%	64.7%	18.6%
Trucks Only	57.8%	60.5%	9.0%	54.4%	78.3%	5.9%	36.4%	64.0%	12.5%
EXTENDED REDUCED SPEED									
All Vehicles	32.2%	53.9%	21.8%	11.3%	41.8%	22.9%	9.6%	34.2%	30.1%
Cars Only	28.9%	48.9%	31.5%	11.2%	42.4%	27.6%	7.3%	27.8%	43.2%
Trucks Only	39.2%	60.5%	17.5%	11.3%	41.7%	21.3%	10.3%	36.3%	26.0%

Table 2: Speed Compliance at MP 256.2, MP 273.1 and MP 289.5

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