Evaluating the Potential of Remote Sensing Rural Road and Travel Conditions

KEVIN A. FRENCH AND EUGENE M. WILSON

Communication of current road and travel conditions may reduce the number of accidents attributable to winter driving conditions in rural mountain states. During the last 5 years, 61.1 percent of the total yearly accidents at the study site occurred during the relatively small percentage of time (9.8 percent) that the road and travel conditions were poor. Use of real-time remote weather information for updating road and travel information was evaluated. Spot speed surveys for different road and travel conditions, road user surveys, snowplow operator reports, and remote weather information system (RWIS) data were analyzed to evaluate the effectiveness of the real-time weather information system. The existing RWIS did not correlate well with the road conditions reported by road users or snowplow operators. An upgrade of the RWIS is needed to improve reliability. The addition of visibility measuring equipment (particle counter) is needed. Additional RWIS sensor locations and automatic speed monitoring should also be considered.

The number of accidents attributable to winter driving conditions on the Interstate road system is a significant problem in Wyoming and other mountain states. One possible solution for addressing the winter accident problem is communication of current road and travel conditions. The main communication objectives are (*a*) to provide the road user with information about the severity of the road and travel conditions so that the road user may determine whether to proceed with a trip and (*b*) to provide the road user with adequate warning so that driving habits may be adjusted.

This paper provides an evaluation of a remote weather information system (RWIS) to assist governmental bodies in updating road and travel information. Real-time road and travel information can be communicated to road users using a variety of devices including changeable message signs (CMSs), road and travel telephone numbers, road and travel information on public radio, and linear radio systems. The key need is to obtain real-time road and travel conditions on rural roads. Presented in the following section are results of a University of Wyoming survey of departments of transportation concerning use of RWIS and adverse road advisory messages.

K. A. French, Traffic Operations Branch, Wyoming Transportation Department, P.O. Box 1708, Cheyenne, Wyo. 82002. E. M. Wilson, Civil Engineering Department, University of Wyoming, Laramie, Wyo. 82070.

EXISTING USE OF RWISs

Several states currently use RWISs for maintenance purposes. The RWIS is used by several agencies to predict when snow/ice control measures will be required. California, Florida, South Carolina, and Wyoming are a few states that have used RWIS for updating or supplementing weather data to determine the road and travel advisories for road users.

The California Department of Transportation (Caltrans) currently uses RWIS in conjunction with changeable message signing to regulate traffic. Road closure information and expected delays are the types of information concerning poor road and travel conditions provided to road users by Caltrans.

The Florida Department of Transportation (FDOT) has used fog detection and warning devices in the past, but these were discontinued due to fog detection device malfunctions. FDOT currently uses wind detection devices and related travel advisories posted on CMSs. South Carolina currently uses a fog detection and warning system (*1*,*2*).

The Wyoming Transportation Department (WTD) currently uses remote weather information systems to detect strong and gusty winds on Interstate 80 near Laramie, Wyoming. An automatic wind warning system consisting of a remote wind speed measuring device and CMSs is currently being used. Strong and gusty winds are measured and compared with predetermined wind speed criteria. If the wind speed criteria are surpassed, a high wind warning message is automatically displayed on CMSs. The criteria used by WTD are wind speeds of 35 mph (56 kph) for dry pavement conditions and 25 mph (40 kph) for icy or snowy pavement conditions. The message that is displayed is wind gusts to xx mph—advise no light trailers. Other states, such as Nevada, also use the CMS to provide wind-related messages. Accurate knowledge of pavement conditions is important to the criteria associated with the Wyoming system. In order to aid in determining conditions other than wind speed, a RWIS was installed at the study site. The RWIS was located approximately 13 mi (21 km) east of Laramie in the 41-mi (66-km) section between Laramie and Cheyenne, which was determined to have the most severe conditions. To evaluate the RWIS, an investigation of accident data was undertaken to determine whether certain user groups needed to be targeted for RWIS information.

ACCIDENT ANALYSIS

The accident data on Interstate 80 between Laramie and Cheyenne were evaluated to determine trends in winter accidents. For 1986 to 1991 there was an average of 193 accidents per year. Of those, 118 accidents occurred when roadway conditions were poor (icy, snowy, or slushy). During this period, the average accident rate for all road users during poor road and travel conditions for the study site was 11.63 (number of vehicles involved per 1,000,000 mi of travel). This was about 13 times greater than the accident rate for all road users during favorable road conditions (0.90). Accident rates were also estimated for local Wyoming, other Wyoming, and out-of-state passenger vehicles and trucks. Traffic volume data, vehicle classification data, snow/ice maintenance data, and accident data were used to estimate accident rates for each combination of vehicle type, driver proximity, and pavement condition (see Table 1). The average accident rate for out-of-state road users was 19.04 (number of vehicles involved per 1,000,000 mi of travel) during poor road conditions. The average accident rate for local Wyoming road users was 12.57 during poor road conditions.

The accident rates for local Wyoming road users in poor road conditions was 10 to 25 times higher than in favorable conditions. The average accident rate for all passenger vehicles was 1.06 for favorable road conditions and 13.99 for poor road conditions. The average accident rate for trucks was 0.74 for favorable road conditions and 9.74 for poor road conditions. The numbers of accidents that occurred with different roadway conditions are given in Table 2.

The yearly number of accidents when road conditions were poor was about 60 percent higher than the yearly number of accidents when road conditions were favorable. The accidents that occurred during poor road conditions happened in a time span that amounted to approximately 10 percent of the total time during the year. Using this knowledge, adverse road and travel conditions were classified and spot speed surveys were conducted during the 1990–1991 and 1991–1992 winters.

SPEED SURVEYS

Speed surveys were incorporated to determine how varying degrees of visability, wind, and pavement conditions affect road user behavior. The speed surveys were conducted adjacent to the RWIS site for eastbound traffic and separated into two categories—passenger vehicles and trucks. The stopwatch method of measuring time over a distance was used to determine the spot speeds. Speed data were obtained for both the passenger vehicle and truck classifications. In total, more than 5,600 independent speed observations were made. The weather-related road and travel conditions were determined as the speed surveys were being conducted. Speed surveys were recorded by time and combinations of visibility, wind, and pavement conditions.

The visibility condition was classified as either favorable or poor. The visibility condition was considered favorable if there was at least 600 ft (183 m) of sight distance. The visibility condition was classified as poor if less than 600 feet (183 m) of sight distance was available. The wind condition was classified as either calm or strong and gusty. The pavement conditions were classified as favorable (dry or wet), slick in spots, or poor (slushy, snowpacked, or icy). The pavement condition was checked at regular intervals during each observation period.

The spot speed surveys were analyzed to determine whether varying degrees of visibility, wind, and pavement conditions

TABLE 1 Estimated Accident Rates[a]

Passenger Vehicles

	Dry or Wet			Icy, Snowy, or Slushy		
Year	Local Wyoming	Other Wyoming	Out of State	Local Wyoming	Other Wyoming	Out of State
1986	0.61	1.36	1.78	11.30	3.74	14.76
1987	1.16	0.47	2.28	15.50	3.22	27.02
1988	1.03	0.45	2.19	15.19	8.49	19.93
1989	1.04	0.14	1.39	10.46	12.00	23.66
1990	0.95	0.28	1.35	7.53	5.61	23.25
1991	0.49	0.68	1.39	12.47	9.52	28.16

Trucks

	Dry or Wet			Icy, Snowy, or Slushy		
Year	Local Wyoming	Other Wyoming	Out of State	Local Wyoming	Other Wyoming	Out of State
1986	0.00	0.00	0.38	8.19	0.00	12.64
1987	2.76	0.00	0.71	21.16	0.00	15.43
1988	3.25	0.69	0.92	31.85	0.00	17.53
1989	0.62	0.00	0.61	5.25	0.00	20.49
1990	0.62	0.00	0.77	0.00	5.24	9.48
1991	1.19	0.00	0.79	11.90	0.00	16.08

[a] Accident rates are number of vehicles involved in accidents per 1,000,000 miles of travel

TABLE 2 Number of Accidents

	Conditions		
Year	Dry or Wet	Icy, Snowy, or Slushy	Total
1986	58	75	133
1987	86	112	198
1988	84	122	206
1989	71	151	222
1990	74	106	180
1991	69	142	211

were significant factors affecting motorist behavior during periods of poor road and travel conditions. The speed survey data were then analyzed using regression analysis procedures. Average speed and percent in the 10 mph pace were the dependent variables used to evaluate the effect of poor road and travel conditions on road users. The average cell sample size contained 333 observations for passenger vehicles and 231 observations for the truck classification.

The dependent variable, average speed, was modeled against the predictors visibility, wind, pavement, vehicle type, and interaction effects of visibility*wind, visibility*pavement, visibility*vehicle type, wind*pavement, wind*vehicle type, pavement*vehicle type, and pavement*pavement. Stepwise model building procedures (forward addition, backward elimination, and maximum R^2) were used to determine the best predictors. The consensus of the three stepwise regression models was a model including visibility, visibility*wind, and pavement as the best predictors of average speed.

The resulting best model for predicting average speed was

$$\overline{S} = 62.5083 - 8.9833(V) + 7.4583(V)(W) - 4.7417(P) \quad (1)$$

where

$\overline{S}$ = average speed (mph) (1 mph = 0.62 kph),
V = visibility (0 = favorable, 1 = poor),
W = wind (0 = favorable, 1 = poor), and
P = pavement (0 = favorable, 1 = slick in spots, 2 = poor).

The resulting coefficient of determination for the model was $R^2 = 0.92$, showing a good relationship between the predictors and average speed. Pavement and visibility were the most important factors affecting average speed. The interaction between visibility and wind was also a significant factor. Vehicle type was not a significant factor affecting average speed during periods of poor road and travel conditions.

The dependent variable, percent in pace, was also modeled using the same predictors. Using the model building procedures, only pavement was found to have an appreciable effect on the percent of road users traveling in the 10-mph pace.

The best model for predicting percent in pace was

$$\text{Percent in pace} = 68.9580 - 7.9072(P). \quad (2)$$

where P is pavement (0 = favorable, 1 = slick in spots, 2 = poor).

The resulting coefficient of determination for the model was $R^2 = 0.72$, showing a fair relationship between pavement and percent in pace. The regression model indicates that as pavement conditions became more adverse, the percent of road users traveling in the 10-mph pace was reduced. The ability of the RWIS to reflect road and travel conditions was investigated using the same classifications.

RWIS, ROAD USER SURVEYS, AND SNOWPLOW OPERATOR REPORTS

Real-time weather data from RWIS were collected from December 1990 to January 1992. The core of the RWIS is a surface sensor and a set of atmospheric condition sensors. The output from each of the sensors is fed to a microprocessor called a remote processing unit (RPU), which converts the output into identifiable conditions and then stores the conditions in memory. The measured weather data recorded by the RPU include presence of precipitation, surface pavement temperature, air temperature, relative humidity, wind speed, and wind direction. The RPU then determines the pavement status and dew point on the basis of the measured parameters. All of the data are updated when a predetermined significant change is measured for any of the seven parameters.

Local commuters and interstate truckers were surveyed to determine their evaluation of road and travel conditions. Local commuters completed questions in a travel diary and Interstate truckers were surveyed using citizens band radio. Road user characteristics and their classification of the road and travel conditions by visibility, wind, and pavement conditions were obtained.

Information concerning road and travel conditions was also obtained from WTD for the study site from December 1990 to January 1992. Snowplow operators described road and travel conditions in terms of visibility, wind, and pavement conditions to radio dispatchers. The radio dispatchers kept a log of road and travel conditions by date and time of day. The results of these data comparisons are summarized in the following section.

RWIS RESULTS

There was little correlation between the visibility reported by the road users and precipitation measured by the RWIS. Precipitation is the only possible indicator of visibility with the present system. The visibility condition was reported as clear 520 times (71 percent), as limited 176 times (24 percent), and as very limited 41 times (5 percent) when no precipitation was present. When precipitation was present, clear visibility was reported 303 times (35 percent), limited 368 times (43 percent), and very limited 185 times (22 percent).

The majority of road users (70 percent) rated the winds as strong and gusty when the RWIS measured wind speeds of 15 to 20 mph (24 to 32 kph). WTD currently uses wind speed criteria for posting advisory wind messages of 25 mph (40 kph) for poor road conditions and 35 mph (56 kph) for dry road conditions.

Pavement conditions reported by the road users did not correlate well with the pavement status provided in the RWIS data. Table 3 contains summaries of these results, which indicate the difficulty of applying a spot detection of road condition to estimate conditions over the entire roadway.

The visibility conditions reported by the snowplow operators also did not correlate very well with the presence of precipitation as measured by the RWIS. Pavement conditions reported by the snowplow operators also did not correlate well with the pavement status provided by the RWIS. These results are contained in Table 4.

Road users generally tended to report less favorable visibility conditions than did the snowplow operators. Road users also reported strong and gusty winds at lower wind speeds as measured by the RWIS than did the snowplow operators. Road users, in general, indicated poorer pavement conditions than the snowplow operators, who most often describe adverse pavement conditions as slick in spots. Although these results indicate overall poor correlation, additional capabilities are possible for RWIS monitoring.

CONCLUSIONS

Safety improvements are needed to reduce the number of winter accidents. Possible solutions for addressing the winter accident problem are education, improved communication of current road and travel conditions, and restriction of travel.

Poor visibility and pavement conditions had the most effect on the average speeds of road users traveling during inclement road and travel conditions. Road users adjusted their travel speeds depending on their perception of the severity of the conditions. Strong and gusty winds should be reported when wind speeds greater than 15 mph (24 kph) are reached, correlating with road user ratings. Current road and travel information needs should be conveyed to the road users so that they can make an informed decision concerning making a trip during varying degrees of adverse winter conditions.

There was very little correlation between the conditions described by RWIS, road user surveys, and snowplow operator reports. The conditions described by the present RWIS did not relate to the overall conditions of the roadway as described by either the road users or the snowplow operators. Therefore, the existing RWIS should not be used solely to determine poor road and travel conditions. The current RWIS does not provide adequate information to accurately determine the road and travel conditions for Interstate 80 between Laramie and Cheyenne. If use of the RWIS to determine road and travel conditions is to be continued, the RWIS should be upgraded to include more weather sensor locations and visibility measurement devices.

RECOMMENDATIONS

A project to develop information on safe winter driving strategies should be performed. The information should address safe advisory speeds to be recommended during specific poor road and travel conditions. Information concerning necessary travel, safe following distances, emergency or evasive maneuvers, and emergency preparedness should be included. Road users should be advised of the risk of traveling during poor road and travel conditions to determine whether their trip purpose justifies the risk. Safe following distances for specific road and travel conditions should be recommended on the basis of available stopping sight distance and pavement condition. Emergency or evasive maneuvers should be recommended concerning the safest places to stop when conditions deteriorate to a level that road users should stop and

TABLE 3 Pavement Conditions, RWIS Versus Road User Surveys

	Road User Surveys						
RWIS Status	Dry	Wet	Slushy	Snow-packed	Slick-in-spots	Icy	Total
Dry	411	62	11	19	236	40	779
Wet	5	12	15	4	34	9	79
Chemical Wet	1	4	3	4	66	58	136
Snow/Ice Alert	39	14	7	44	285	165	554
Total	456	92	36	71	621	272	1548

TABLE 4 Pavement Conditions, RWIS Versus Snowplow Operator Reports

	Snow Plow Operator Reports						
RWIS Status	Dry	Wet	Slushy	Snow-packed	Slick-in-spots	Icy	Total
Dry	86	21	0	5	134	4	250
Wet	1	7	0	5	39	2	54
Chemical Wet	0	0	0	6	46	0	52
Snow/Ice Alert	8	1	0	8	147	28	192
Total	95	29	0	24	366	34	548

wait for conditions to improve. Emergency preparedness information should be assembled so that stranded road users know what to do and have the proper supplies in case of emergency. Information concerning these safe driving strategies should be conveyed to the traveling public in drivers' license examination procedures, port-of-entry handouts, and local media to maximize exposure.

Permanent traffic speed monitoring stations could be installed with additional improved RWIS stations that include particle counters to measure visibility. Reductions in the average speed or percent in pace of road users should be used in conjunction with the expanded RWIS data to determine the road and travel conditions being encountered by the road users.

The additional weather sensor stations would improve the system by sensing poor road and travel conditions at more than one location. This would improve reliability by indicating poor road and travel conditions that would be applicable to a wider segment of the roadway between Laramie and Cheyenne.

The wind speed criteria currently used by WTD for high wind warnings should be lowered to levels consistent with the road user ratings. The RWIS pavement status can be used to supplement other sources of information but should not be used alone because of the poor single point correlation of the pavement status and actual conditions over the 41-mi (66-km) distance between Laramie and Cheyenne. More RWIS sensors would provide the pavement status at more locations, improving the reliability of the system.

ACKNOWLEDGMENTS

This cooperative study was funded by the U.S. Department of Transportation's University Transportation Center's Program through the Mountain-Plains Consortium, WTD, and the University of Wyoming. Special recognition is given to Mike Gostovich, A. J. Schepp, Joe Yovich, and the members of the Traffic Operations Branch and Laramie Maintenance District who assisted in the data collection.

REFERENCES

1. M. R., Parker, Jr. *Synthesis of Safety Research—Adverse Environmental Conditions.* Federal Highway Administration, U.S. Department of Transportation, 1990.
2. R. N. Schwab. *Special Report 134: Minimizing the Hazard of Restricted Visibility in Fog.* HRB, National Research Council, Washington, D.C., 1973.

The authors are solely responsible for the contents of this paper and the views expressed do not necessarily reflect the views of the research sponsors.

Publication of this paper sponsored by Committee on Winter Maintenance.