Current Practices in Transportation Management During Inclement Weather

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Abstract. The Road Weather Management Program of the Federal Highway Administration (FHWA) has documented transportation management practices used during inclement weather. Best management practices include road weather and traffic surveillance to assess threats to transportation system performance, arterial and freeway management to regulate roadway capacity, as well as dissemination of advisory information to influence traveler decisions and driver behavior. These management practices are employed in response to various weather threats including low visibility, high winds, precipitation, hurricanes, flooding, and avalanches. Weather-related transportation management practices (1) improve mobility by increasing roadway capacity and promoting uniform traffic flow, (2) increase public safety by minimizing accident risk and exposure to hazards, as well as (3) enhance the safety and productivity of road maintenance personnel.

INTRODUCTION

The Road Weather Management Program of the Federal Highway Administration (FHWA) has documented best practices utilized by traffic managers, maintenance managers, and emergency managers in response to various weather threats. This paper summarizes best management practices that demonstrate the entire information thread, from information about a weather threat to the highway system to information about system performance (i.e., safety, mobility, and productivity). The information thread begins with surveillance of weather, road, traffic, and other conditions to identify threats to transportation system performance. Threat information is typically gathered through surveillance systems that detect, monitor, and transmit data from the roadway to central systems accessed by managers. Surveillance data may also be used to predict adverse weather or pavement conditions. Based upon credible threat information, managers execute operational practices to enhance system performance. The results of a FHWA effort to document best management practices are available on CD-ROM.

CURRENT TRANSPORTATION MANAGEMENT PRACTICES

Weather-related traffic management can be divided into several different subject areas including arterial management, freeway management, traveler information, as well as road weather and traffic flow modeling. This paper highlights best practices in the first three areas. Arterial and freeway management practices improve transportation outcomes under adverse weather conditions through surveillance techniques to assess weather threats and the application of control techniques. Traveler information techniques make use of surveillance data to notify motorists of localized environmental conditions.

Arterial Management

Arterial management focuses on the efficient movement of vehicles on arterial (and other non-freeway) roads. Managers operating signal control systems can respond to changing conditions by implementing different signal timing plans depending upon the time of day, traffic volumes, or weather and pavement conditions. For example, a traffic manager may alter traffic signal timing when roads are wet or icy to accommodate longer start-up times and slower travel speeds.

The City of Clearwater, Florida operates a computerized traffic signal control system with a rain preemption feature to clear traffic from Clearwater Beach. Thunderstorms typically occur in the afternoon causing sudden, significant increases in traffic volume exiting the beach along the Memorial Causeway (i.e., Route 60). When a rain gauge installed on the beach detects a predetermined amount of rainfall, the signal system computer issues a command to downtown traffic signals to implement timing plans with longer green times for inbound approaches. Vehicle detectors on the Memorial Causeway (shown in Figure 1) measure the density of traffic queues. When traffic volumes return to normal levels, the computer restores normal timing plans. Mobility is enhanced by modifying traffic signal timing to prevent traffic congestion during rain events. (10)

Figure 1 – City of Clearwater Map

Freeway Management

Freeway management techniques are employed to regulate roadway capacity by permitting or restricting traffic flow. In response to weather threats, traffic managers may use various control methods including access restriction, speed management, and evacuation traffic management.

<u>Access Restriction</u>

Access restriction during inclement weather may involve the closure of roads and bridges, permission of access only to vehicles with specified equipment (such as tire chains) and restrictions applied to certain vehicle types. The Montana Department of Transportation (DOT) manages vehicle access on Interstate 90 in the Bozeman/Livingston area. Severe wind tunnel conditions frequently occur on an eight-mile section of the interstate freeway. The Montana DOT has installed four dynamic message signs (DMS) to warn motorists of high wind conditions and restrict access to high profile vehicles during severe winds.

Traffic and maintenance managers are alerted by a road weather information system (RWIS) when wind speeds in the area exceed 20 mph (or 32 kph). An advisory message—"Caution: Watch For Severe Crosswinds"—is displayed on DMS when wind speeds are between 20 and 39 mph. When severe winds (over 39 mph or 63 kph) are detected, a restriction message is displayed directing high profile vehicles to exit the interstate and detour through Livingston. A typical restriction message reads "Severe Crosswinds: High Profile Units Exit". Before the message signs were installed, maintenance personnel had to erect barricades on the freeway to prevent these vehicles from entering the affected highway section and being blown over or blown off of the road. Restricting access under high wind conditions has improved road safety as well as the productivity and safety of maintenance staff. (15)

<u>Speed Management</u>

Speed management involves the dissemination of safe travel speed information to motorists during adverse conditions. The Utah DOT manages speed during fog events on a low-lying, two-mile segment of Interstate 215 in Salt Lake City. Field data from four visibility sensors and six vehicle detector sites are collected and transmitted to a central computer system. The computer system utilizes visibility distance, vehicle speed, and vehicle classification data in a weighted average algorithm to determine when conditions warrant speed limit reductions. If visibility distance falls below 820 feet (or 250 meters), the central computer automatically displays advisory messages on roadside DMS. Messages displayed for various visibility ranges are shown in Table 1.

Visibility Range	*Displayed Message*
656 to 820 feet (200 to 250 meters)	"Fog Ahead" alternating with "Poor Visibility"
492 to 656 feet (150 to 200 meters)	"Max Speed 50" alternating with "Poor Visibility"
328 to 492 feet (100 to 150 meters)	"Max Speed 40" alternating with "Poor Visibility"
197 to 328 feet (60 to 100 meters)	"Max Speed 30" alternating with "Poor Visibility"
Less than 197 feet (60 meters)	"Max Speed 25" alternating with "Poor Visibility"

Table 1 – Utah DOT Low Visibility Messages

Exceedingly cautious drivers sped up when advisory information was displayed, resulting in a 15% increase in average speed from 54.0 to 62.0 mph (or 86.8 to 99.7 kph). This speed increase caused a 22% reduction in speed variance from 9.5 to 7.4 mph (or 15.3 to 11.9 kph). Notifying motorists of poor visibility conditions and managing travel speeds improved mobility and safety by promoting more uniform traffic flow, which minimized accident risk. (6, 10)

<u>Evacuation Traffic Management</u>

Evacuation traffic management is often necessitated by severe weather events such as flooding and hurricanes. Opening shoulder lanes to traffic and contraflow are common management practices employed in response to approaching hurricanes. Contraflow operations (as shown in Figure 2) reverse traffic flow on coast-bound lanes during an evacuation and on in-bound lanes during reentry operations after a hurricane. (17)

Three million people were evacuated from Florida, Georgia, North Carolina and South Carolina prior to landfall of Hurricane Floyd in September, 1999. Utilizing storm track, wind speed, and precipitation forecasts in combination with topographic and population data, traffic and emergency management agencies at local, state, and federal levels coordinated to evacuate residents from areas threatened by coastal storm surge and inland flooding.

Because managers with the South Carolina DOT and the State Highway Emergency Patrol (SHEP) had not agreed on a lane reversal plan prior to Hurricane Floyd, contraflow was not used during the evacuation. Consequently, there was severe congestion on Interstate 26 between Charleston and Columbia. Travel times—which are normally two to three hours—ranged from 14 to 18 hours. The maximum per lane volume on the interstate was roughly 1,400 vehicles per hour.

Traffic and emergency managers quickly developed a contraflow plan for reentry operations. Westbound lanes were reversed for use by coast-bound traffic and portable DMS and highway advisory radio (HAR) transmitters were deployed along the interstate to alert drivers. As a result, the maximum volume during reentry was 2,082 vehicles per hour per lane—a 49% increase over the peak evacuation volume. Evacuation traffic management improved mobility by significantly increasing roadway capacity and traffic volume. (12)

Figure 2 – Contraflow During Evacuation

Traveler Information

Traffic, maintenance and emergency managers disseminate information to the public to influence travel decisions. The provision of road weather information allows travelers to make informed decisions about departure time, travel mode, route selection, vehicle type and equipment, as well as driving behavior (e.g., increase headway and decrease speed). Traveler information is furnished via roadside motorist warning systems, web-based applications (i.e., the Internet), interactive telephone systems, and other broadcast media. Traveler information systems are employed for various weather threats including low visibility, high winds, poor pavement conditions, flooding, and avalanches.

<u>Adverse Weather Warning System</u>

On a section of Interstate 84 in southeast Idaho and northwest Utah, traffic managers present traveler information on roadside DMS to enhance roadway safety and mobility. Atmospheric, pavement, and traffic data are collected by sensor systems along the freeway and transmitted to a central computer. Idaho DOT traffic managers are alerted when driving conditions deteriorate due to low visibility, high winds, precipitation or snow-covered pavement.

Average vehicle speeds with and without advisory messages were compared under adverse weather and pavement conditions. When traffic managers displayed condition data during high winds (above 30 mph or 48 kph), average speeds decreased by nearly 24% from 55 to 42 mph (or 88 to 68 kph) and speed variance was reduced. When high winds occurred simultaneously with moderate to heavy precipitation, speeds were 13% lower when warnings were provided. Mean speeds were 47 mph (or 76 kph) without advisory information, and roughly 41 mph (or 66 kph) with condition warnings. When the pavement was snow-covered and wind speeds were high, average speed fell from approximately 55 to 35 mph (or 88 to 57 kph)—a 35% decline with notification via DMS. (4)

Low Visibility Warning System

In December, 1990 a 99-vehicle collision on Interstate 75 in southeastern Tennessee prompted the design and deployment of a fog detection and warning system. The system covers a three-mile, fog-prone section above the Hiwassee River and eight-mile road sections on each side of the river. A central computer system predicts and detects conditions conducive to fog formation by continually monitoring data from two environmental sensor stations (ESS), eight fog detectors and 44 vehicle speed detectors. The computer system alerts traffic and emergency managers when established threshold criteria are met, correlates field sensor data with predetermined response scenarios, and recommends responses based upon prevailing field conditions.

Figure 3 – VSL Sign

Responses include warning motorists via two HAR transmitters, flashing beacons atop six static signs, and ten DMS; reducing speed limits with ten variable speed limit (VSL) signs (as shown in Figure 3); and restricting access to the affected road segment using eight ramp gates. Managers select preprogrammed DMS messages (see Table 2), prerecorded HAR messages, and appropriate speed limits (i.e., 65, 50 or 35 mph) based upon response scenarios proposed by the system. Under worst-case conditions (i.e., visibility less than 240 feet or 73 meters), the Highway Patrol activates automatic ramp gates to close the freeway and detour traffic to US Route 11.

Conditions	*Displayed Messages*
Fog Detected	"Caution" alternating with "Fog Ahead Turn On Low Beams"
Speed Limit Reduced due to Fog	"Fog Ahead" alternating with "Advisory Radio Tune To XXXX AM"
	"Fog Ahead" alternating with "Reduce Speed Turn On Low Beams"
	"Fog" alternating with "Speed Limit XX mph"
Roadway Closed due to Fog	"Detour Ahead" alternating with "Reduce Speed Merge Right"
	"I-75 Closed" alternating with "Detour →"
	Flashing "Fog Ahead" with "Advisory Radio Tune To XXXX AM"

Table 2 – Tennessee DOT Low Visibility Messages

There were over 200 fog-related crashes—with 130 injuries and 18 fatalities—on this road section from 1973 (when the interstate opened) to 1994 (when the system began operating). Safety has significantly improved since the warning system was implemented, as no fog-related accidents have occurred in the area. (2, 3)

<u>Avalanche Warning System</u>
On US Highway 189 near Jackson, the Wyoming DOT uses an avalanche warning system to detect avalanches, warn motorists approaching the area, and alert maintenance personnel working in the area. The system utilizes cables, with tilt switch sensors, strung across the avalanche path 980 feet (or 300 meters) above the roadway. The computerized warning system continuously monitors sensors located in the avalanche path.

At the onset of an avalanche, flashing beacons atop static road signs are automatically activated to caution motorists, and audible alarms in maintenance vehicles are triggered to notify maintenance staff that may be in the avalanche path. The avalanche warning system improves safety by minimizing risks to the traveling public and to maintenance personnel. The system also facilitates timely inspection of the roadway after an avalanche, snow and debris removal activities, and road closure or rescue operations. (13)

<u>Web-Based Flood Warning System</u>
The City of Palo Alto, California was flooded in February, 1998 when three creeks spilled over their banks. This event encouraged the City to develop a web-based water level monitoring system to warn of potential flooding. Ultrasonic water level sensors were installed at five bridge locations to detect high water or flood conditions. The sensors determine water levels by emitting sound waves to measure the distance from a transducer to the water surface. A video camera is also installed at one location to visually observe water levels. Field sensor data are transmitted to the City's central Supervisory Control and Data Acquisition (SCADA) system. Current and historical environmental data, as well as video images, are posted on the Creek Level Monitor web site (www.city.palo-alto.ca.us/earlywarning/creeklevels.html) for viewing by managers and City residents. Additionally, a telephone warning system is automatically activated to advise residents of potential flooding when high water is detected. Traffic and emergency managers access online information to make control and response decisions. Residents may utilize online data and telephone warnings to make travel and safety decisions. As shown in Figure 4; current water level, 12-hour water level trend, 24-hour rainfall amount, annual rainfall amount, current temperature, and tidal data are displayed and updated every three minutes.

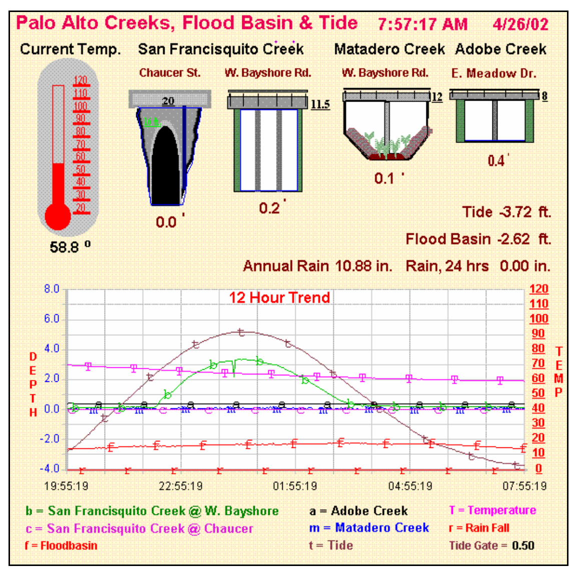

Figure 4 – Creek Level Monitor Website

Before the water level monitoring system was deployed, emergency management personnel traveled to bridge locations to physically check water levels and monitor the storm drain system. By eliminating the need for field measurements, the monitoring system has increased the productivity of City personnel while enhancing public safety through the provision of timely, relevant road weather information. (1, 5)

<u>Interactive Telephone Information System</u>

The Advanced Transportation Weather Information System (ATWIS) produces tailored road weather information for approximately 37,000 highway miles in North Dakota, South Dakota, Minnesota and Montana. The ATWIS integrates weather analysis data with state DOT road attribute data to furnish users with route-specific road condition reports and six-hour weather forecasts extending roughly 60 miles (or one hour) in their direction of travel. Cellular telephone users receive customized information via interactive voice response technologies by dialing #7233 (or #SAFE™). A typical #SAFE™ message, which can be found at www.meridian-enviro.com/safe/sample_message.html, reads:

> "The following road conditions report and weather forecast is sponsored in part by the State Department of Transportation. For travelers on Interstate 00 eastbound from mile marker two hundred seventy-two traveling toward Local City. Traffic speeds are reduced due to poor visibility. Roadway is snow-covered. Drivers should stay alert to changing conditions. The forecast until 9:00 Central Time this Tuesday evening: Skies will be overcast becoming mostly cloudy. Visibility will be less than one-quarter mile changing to near zero with blowing snow. There will be frequent moderate snow ending. Winds will be ten miles per hour to fifteen miles per hour gusting from the north-northwest changing to thirty-five miles per hour gusting to forty from the northwest. Temperatures will range from eight to ten degrees decreasing to minus two to minus six degrees." (14)

The information system provides useful road weather data promoting safe and efficient travel. A survey found that over 94% of #SAFE™ users believe that ATWIS has safety benefits. Another user survey indicated that ATWIS data was easy to access, accurate, and useful. Many users felt that the system would be beneficial for both pre-trip planning and en-route applications. (7, 8, 9)

CONCLUSIONS

The goal of the Road Weather Management Program is to promote the deployment of effective road weather management practices in order to improve transportation system performance under inclement weather or adverse environmental conditions. This paper described several practices of traffic, maintenance, and emergency managers illustrating how current and predicted weather information can be used to make operational decisions that enhance the performance of transportation systems.

Transportation management practices such as weather-related traffic signal timing, access restriction, speed management, evacuation traffic management, and traveler information dissemination (1) improve roadway mobility by increasing roadway capacity and promoting uniform traffic flow, (2) increase public safety by minimizing accident risk and exposure to weather-related hazards, as well as (3) enhance the safety and productivity of road maintenance staff.

By integrating road weather data into decision-making processes, managers can effectively counter weather-induced problems and deliver credible, customized traveler information that allows motorists to avoid unsafe conditions and better cope with weather effects on roadways. Further details about best management practices are available on the Road Weather Management Program CD-ROM, which contains case studies, publications and other resources for traffic managers.

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