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DECISION SUPPORT SYSTEMS FOR WINTER ROAD WEATHER: OPPORTUNITIES FOR RADAR DATA

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1 INTRODUCTION

According to the National Highway Traffic Safety Administration (NHTSA), adverse weather impacts the nation's streets and highways resulting in 7,000 deaths and 800,000 injuries per year. Between 1989 and 1998 weather was found to be a factor in 28% of all highway accidents. Injuries and deaths that occur when snow and ice are present total 63,000 and 680, respectively (1999 data). Weather also contributes significantly to congestion and plays a role in incident, traffic and emergency management. The economic impact of weather is estimated to be $42 billion per year. The Office of Federal Coordinator for Meteorology (OFCM) describes the impact of weather on the surface transportation system in a recently published document (OCFM, 2003). This report describes national weather information needs for highways, rail, transit, marine and pipelines. It is clear from this document that more needs to be done to address the unmet needs for improved weather information for our mobile society.

Although weather has a major influence on the surface transportation system, it has not received the attention it deserves given the potential safety and efficiency benefits that could be realized if the users of the highway system had more precise information on the conditions along their route.

This paper discusses the potential of incorporating radar data in future surface transportation decision support systems. Although it focuses mainly on winter road maintenance, other application areas such as traffic, and incident and emergency management are discussed.

2 USER NEEDS ASSESSMENT

In fiscal year 2000, the U.S. Federal Highway Administration (FHWA) Road Maintenance Management Program began an initiative to gather surface transportation weather decision support requirements from State Department of Transportation (SDOT) personnel (FHWA, 2000).

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The objective of this effort was to identify specific needs and priorities for weather information and to begin a process of conducting research and demonstration programs of new weather capabilities. Substantial benefits can be realized if weather information and forecasts are improved, are more specific, more timely, and tailored for surface transportation decision makers who are not meteorologists. Highway operators defined a need for better strategic and tactical decision support. Strategic support was generally defined as decisions that need to be made in the 12-48 hour timeframe, whereas tactical support was defined as a decision period of 0-12 hours.

Better weather support for winter road maintenance was one of the highest priority areas for attention identified by highway operators. Because of this finding, the Federal Highway Administration (FHWA) initiated a project in 2000 to develop a prototype winter road Maintenance Decision Support System (MDSS) that combines weather and road condition prediction with rules of practice for road anti- and deicing.

Five national research centers and a stakeholder group of approximately 75 persons representing DOT, commercial weather provider and other research organizations have participated in the development of the functional prototype MDSS. The participating national labs include the Cold Regions Research and Engineering Laboratory (CRREL), National Center for Atmospheric Research (NCAR), Lincoln Laboratory (MIT/LL), National Severe Storms Laboratory (NSSL), and the Forecast Systems Laboratory (NOAA/FSL).

The MDSS Project goal is to develop a prototype decision support tool that provides specific treatment recommendations for snowplow routes. Treatment recommendations include treatment type (chemical, sand, plow, etc.), rate, timing, and location. In order to provide this information, the prototype MDSS utilizes output from several numerical weather prediction models, a road temperature model, rules of practice for anti- and deicing, and a fuzzy logic data fusion system that combines model and observational data (Mahoney and Myers, 2003; Hallowell and Blaisdell, 2003).

During the requirements definition phase of the project, the users strongly indicated that their first priority was to have a system that allowed them to do a better job of strategic planning, which required that the MDSS system focus on road condition predictions 12-48 hours into the future. Because of this requirement, the current version of the MDSS is designed solely as a weather and road condition prediction system. Radar and satellite data were only used to initialize the "hot start" mesoscale models provided by FSL.

The MDSS was demonstrated in Iowa during the winter months of 2003. Shortly after the Iowa demonstration began, the users identified the lack of a tactical component as a system limitation. They wanted better weather and road condition guidance during the storm event. It became clear that a fully operational MDSS would require tactical components with radar data being a key input.

3 RADAR DATA OPPORTUNITIES

In this section, opportunities for using radar data to support safe and efficient highway operations are provided for several operational categories.

3.1 Winter Road Maintenance

Based on MDSS user feedback and preliminary results from the MDSS field demonstration, it can be concluded that the winter road maintenance community could benefit greatly if future winter road maintenance decision support systems included a tactical component. A tactical component must include a current analysis of precipitation conditions plus a nowcast (0-2 hour prediction).

Needed parameters include precipitation type (e.g., snow, ice, rain), precipitation rate (liquid equivalent), snowfall rate (depth/hour), temperature and wind speed. Precipitation rate is a critical parameter as it has a major influence on determining the optimum treatment plan. Current automated weather stations do not adequately measure precipitation rate in real time, particularly light winter precipitation and intensities can vary greatly between plow routes making any single measurement suspect along other nearby routes.

Radar data integrated and calibrated by local surface observation data will play a key role in tactical decision support systems that address winter road maintenance.

Winter road maintenance decisions are generally based on having answers to the following questions specific to each maintenance route:

- When will the event start and stop?
- How is the road temperature changing?
- When will the roads freeze?
- What type of precipitation will fall?
- How much precipitation will fall and at what rate will it fall?
- What type of mitigation (treatment) should be performed (salt, sand, anti-icing chemicals)?
- When and where should the treatment(s) be performed?
- How long will the treatment(s) last?

Because the precipitation type and rate impact the road temperature and treatment requirements, an accurate measurement of precipitation is required. Light precipitation amounts (~0.1mm/hr) are particularly important. A single layer of snowflakes can significantly reduce friction and will require treatment. Road maintenance personnel typically have radar graphics available to support their operations, but the weaker intensities are often filtered out due to thresholding. The ability to view radar data is helpful, but as non-meteorologists, users are often misguided by anomalous propagation (AP), bright bands due to melting and virga echoes.

Road maintenance practitioners have expressed a desire to have an integrated decision system to support tactical winter operations. What is desired is a system that combines radar data with road heat balance models and rules of practice. The desire is to have a real-time indication of snowfall rate and accumulation depth for each plow route. In addition, the liquid equivalent needs to be provided and combined with chemical concentration algorithms so an indication can be provided for when the chemicals used for road anti- and deicing (e.g., NaCl, $CaCl_2$, $MgCl_2$) may fail due to dilution.

What may be needed is a decision support system similar to the Weather Support for Deicing Decision Making (WSDDM) system, which was developed for the FAA as an aircraft deicing decision support system. WSDDM utilizes NEXRAD radar data, standard surface weather observations, and real-time snow gauge data (Rasmussen et al., 2002). A combination of WSDDM and MDSS technologies could provide a solid framework for a tactical winter maintenance decision support system.

It goes without saying that timely, high resolution, calibrated, and quality controlled radar data are required to support these functions.

3.2 Incident Management

Incident management involves preparing for and responding to accidents or incidents (no crash) that impact the normal flow of traffic. Many factors contribute to incidents including excessive speeds, tailgating, work zones, curiosity slowdowns, and sun glare. Weather, particularly rain, snow, ice and low visibility has a significant impact on the incident rate.

Individual incidents and their impact on traffic flow could be reduced if the travelers and incident responders knew where the bad weather was occurring. For example, if personnel at the traffic management center knew there was a high correlation between wet roads and incidents in a particular location, they could position police and tow vehicles appropriately to respond just before the

weather event occurs. This type of capability is already coming to fruition in the commercial marketplace. Highway traffic management centers often use Geographic Information Systems (GIS) to monitor and manage their assets. Weather information provided in a GIS format allows one to integrate road and weather data and alert users when 'bad' weather will intersect a critical part of the highway infrastructure. It is expected that these types of products and capabilities will expand as their benefits are demonstrated and realized.

3.3 Emergency Management

Weather impacts emergency management operations in several ways, but for the sake of brevity, only its impact on evacuations will be discussed here. There is renewed attention on the need to be prepared to respond to disasters, particularly those involving chemical, nuclear, and biological agents. Knowledge of where hazardous plumes will flow is critical not only for first responders, but to those responsible for managing the evacuation process. In the early moments after a catastrophic event, people tend to evacuate radially away from the center of activity.

A radial evacuation can be dangerous if the evacuees are stuck in traffic as the plume moves through the area. It is critical that first responders and emergency management personnel know the location and direction of movement of hazardous plumes. Detailed knowledge of the wind field cannot be accurately analysed or predicted without using all surface observations, particularly Doppler radar wind data. The wind field in the boundary layer is strongly influenced by local terrain, gravity currents and convection. Anyone who has analysed radar wind data knows how complex the wind field can be; therefore it is imperative that radar data be part of any real-time plume prediction system. In order to resolve the wind field, radar data (and lidar data if available) must be integrated with surface observation data, thermodynamic and high-resolution weather and plume dispersion models. First responders and highway emergency management personnel responsible for evacuating an area will need the best available information in real time and at their fingertips.

3.4 Vehicle Information Systems

There are several technologies that are coming together that will change the way we travel and receive information while on the road. Global Positioning System (GPS) navigation, integrated vehicle mapping systems, and real-time communication capabilities (e.g., telematics) will be standard equipment in cars within 5-8 years. These voice-activated systems will provide real-time accident, incident, traffic and weather information and will suggest alternate routes to minimize travel time.

Knowledge of current weather, particularly precipitation type and rate, and its impact on travel will be a key part of these information systems. Given that the driver is the ultimate verification system, weather data accuracy will be critical.

3.5 Traffic Management

State DOTs recognize that the number of cars is increasing much faster than lane miles. The only way to reduce the occurrence of congestion is to be more proactive in managing traffic and to provide the travellers more information so they can optimise their routes. Radar data can play an important role for traffic management because a large fraction of traffic slowdowns are due to precipitation.

New traffic management technologies include variable message signs, ramp metering, variable speed limit signs, and information systems such as the national "511" telephone based road information system. In the near future, radar data will very likely be integrated into these traffic management systems. For example, if a traffic management system could identify where precipitation was occurring along certain stretches of road, the information about the conditions could be automatically posted on variable messages signs. Precipitation type and rate information could be used to generate different messages on the signs in order to affect driver behavior. If heavy snow was measured in a particular area, alternate routes could be suggested. If the radar measured strong winds, wind alerts for high profile vehicles could be issued to reduce the chance of an incident or accident, which would clearly impact traffic. Some of these capabilities exist today from data collected from road weather and pavement sensors, but their coverage area is much smaller than radar. Coupling radar to these systems would vastly improve the coverage area. As mentioned previously, in-vehicle information systems have significant potential as the road weather information can be delivered directly to the driver. Commercial and personal vehicle drivers will be able to use the information to minimize the chance of getting caught in poor traffic conditions. Perhaps the problem of the future will be to ensure that too many people don't make the same reroute choice, which would only serve to move the traffic to other corridors.

4 CONCLUSIONS

The overall success of decision support systems focused on surface transportation end users will be measured by their ability to measure and predict weather and road conditions with enough accuracy that decision makers will feel comfortable using them.

A major objective of the FHWA Road Weather Management Program is to raise the awareness of the surface transportation community that weather has a significant impact on the transportation system and any serious attempt to improve its efficiency has to address weather and its overall impact on the system.

Precipitation has a significant impact on road safety, efficiency and capacity. Real-time information on its location, type and rate must be provided to a diverse group of end users (e.g., travelers, commercial shippers, emergency personnel, traffic managers, etc.) in the context of a decision support system to optimize their operations. The role of radar data in the decision process will increase dramatically as traffic management and in-vehicle information systems and communication networks are developed and implemented across the surface transportation infrastructure. Current and planned radar data upgrades such as the availability of Level-II data, improved AP suppression, dual polarization, and techniques that dynamically calibrate precipitation rates using gauge data, will go a long way to improve the timeliness and accuracy of these critical datasets.

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