WHERE THE WEATHER MEETS THE ROAD

A RESEARCH AGENDA FOR IMPROVING ROAD WEATHER SERVICES

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INTRODUCTION

Weather significantly affects the safety and capacity of travel on roadways. Transport Canada data reveal that in the 1990-98 period, an annual average of 364 fatal and over 21,500 road accidents were associated with winter road conditions (loose snow, packed snow or ice, and slush). A further 50 or so fatalities annually were associated with reduced visibilities in fog. Loss of traction due to rain also accounts for a large number of accidents. In the United States (US), adverse weather is associated with more than 1.5 million vehicular accidents annually, which result in about 800,000 injuries and 7,000 fatalities. Inclement weather, such as snow, rain, fog, and ice, can greatly impair roadway conditions. As a result, US drivers endure the frustration of more than 500 million hours of weather-related delay annually on highways, affecting both personal lives and economic productivity. Hurricanes and severe snowstorms can cripple regional transportation systems and cause many lost work days for companies and governments. Routine disruptive weather, such as small snowfall events which occur very frequently in winter in Canada, is responsible for a large proportion of the delays and accidents in Canada.

Too often, people believe that little can be done about the adverse effects of weather on roadway transportation. On the contrary, we are tantalizingly close to providing drivers and traffic managers with real-time weather and routing information thanks to advances made by both the transportation and meteorological communities. For this reason, the US is organizing and investing in a focused road weather research program that brings these communities together to deliver, over the course of the next 15 years, much better road weather services to their nation, saving lives and reducing injuries while improving efficiency of highway systems.

This is a clear attempt on the part of the US to 'accelerate the pace of innovations in transportation'. This paper will describe the US work on defining their road weather research agenda as well as the study's main proposals and look at efforts in Canada and then draw conclusions.

Developments in the United States

The Federal Highways Administration (FHWA) sought the assistance of the US National Research Council (NRC) of the National Academies to examine what needs to be done from the research, development, and technology transfer perspectives to improve the production and delivery of weather-related information for the nation's roadways. In response, the Committee on Weather Research for Surface Transportation was formed. The committee composition included one Canadian and was as follows:

- **John Snow** (*Chair*), University of Oklahoma;
- **Elizabeth Carter**, WeatherExtreme, LLC;
- **Brad Colman**, National Weather Service;
- **Dennis Christiansen**, Texas A&M University;
- **Paul DeLannoy**, Environment Canada;
- **Francis Francois**, American Association of State Highway and Transportation Officials (ret.);
- **George Frederick**, Vaisala, Inc.;
- **Frances Holt**, NOAA's National Environmental Satellite, Data, and Information Service;
- **Margaret A. LeMone**, National Center for Atmospheric Research;
- **Curt Pape**, Minnesota Department of Transportation;
- **Leland Smithson**, American Association of State Highway and Transportation Officials;
- **Daniel Stock**, American Transportation Research Institute (through April 2003);
- **Richard Wagoner**, National Center for Atmospheric Research;
- **Amanda Staudt** (*Study Director*), Board on Atmospheric Sciences and Climate.

US NRC committees are formed for a specific task. The Committee on Weather Research for Surface Transportation was formed in January 2003 and completed its work by December 2003 with the report results first presented nearly simultaneously within both the transportation and meteorological communities in the US in January 2004 at the Transportation Research Board and at the American Meteorological Society annual congresses held in Washington, D.C. and Seattle, Washington respectively. The Committee met five times and received numerous briefings from transportation and meteorological community experts. Writing commenced almost immediately and became particularly intensive in the fall of 2003.

The Road Weather System of 2020 Vision

Recent and anticipated advances in meteorology, roadway technology, and vehicle systems offer great opportunities to improve road weather decision making in multiple areas – extending to the surface transportation system the same access to sophisticated meteorological services which have been enjoyed for some time by the aviation community. Several of the building blocks of the road weather system of the future are in place or under development, and roadway users are already benefiting from some recent advances. Road weather systems could advance very

quickly—probably within the next 15 years—if some existing technologies could be brought together elegantly.

Examples abound. The road weather system of 2020 envisioned in the report would include a **robust new observation and communication "infostructure"** that will make information available to roadway users where and when they need it. This infostructure overlays the roadway infrastructure and would include: a data collection network, such as sensors embedded in the roadway and video monitoring devices at key points; a telecommunication system; and traffic management centers that receive and work with the data and then disseminate information to users. The infostructure would take advantage of advances in sensor technology, information technology, GPS, data management, computing, and geographical information systems, among others.

Important decisions—such as when to slow down, when to salt roads for snow and ice, and when to pour or not to pour concrete—would be supported by "end-to-end" **model-based tools to support decisions** that integrate several elements: real-time observations of current weather, traffic, and road conditions; numerical weather predictions; models of traffic flow given observed conditions; and rules of practice.

Cars and trucks of the future will be able to detect and respond to road weather conditions with ease and could stay in constant communication with weather information providers, traffic control centers, and other vehicles. These **smart vehicles** will inform drivers immediately of poor road conditions and of any obstacles ahead, with access to tools that determine optimum routes.

High costs of controlling snow and ice on roadways demand taking the guess work out of winter maintenance decisions. This is especially true in Canada. **Enhanced roadway maintenance** will be able to provide highly targeted weather information and decision support models that codify best practices and include cost-benefit analyses. The United States has already taken the work lead in developing sophisticated prototypes of this sort of winter road maintenance decision support tool.

New highway construction has decreased markedly, yet the demand for roadway capacity continues to increase. Roadway operators are challenged to manage traffic with ever increasing efficiency, which is made even more difficult in the event of severe weather. **Enhanced traffic and emergency management** will utilize traffic simulation models that dynamically forecast how traffic will most likely respond to weather, construction, accidents, and other road closures.

JOURNEY TO THE FUTURE – STUDY RECOMMENDATIONS

This vision of the road weather system of the future can be achieved only by addressing a number of gaps in existing knowledge and technology. These gaps reflect, at least in part, the lack of integration between surface transportation and meteorological research and development activities. Therefore, the committee recommended that the United States establish a

focused and coordinated national road weather research program to provide leadership and overarching direction for the road weather community.

Transportation research and management are highly decentralized and largely implemented by states; meteorological research and operations are spread across several federal laboratories, universities, and research centers. The private sector has provided many of the targeted road weather services to date; its role will likely expand in the future. Centralized leadership at the federal level is essential in integrating these resources, setting research priorities, administering grants, providing a central repository for research findings, ensuring accountability, and fostering the transfer of new knowledge and technology to operational practice.

The report recommended that the FHWA have the lead role in the national road weather research program, with the US National Oceanic and Atmospheric Administration (NOAA), which includes the US National Weather Service, as a key partner. It was recommended that long-term dedicated funding for road weather research sufficient to achieve the program's goals should be established as new funding within the FHWA. Based on an assessment of unmet needs and costs for comparable research activities, the report estimated that the research program will require on the order of $25 million per year for 15 years.

As a framework for this road weather research program, the report recommended the following five key research and development foci:

1. a robust, integrated observational network and data management system specifically designed to meet the needs of enhanced road weather research and operational capabilities;
2. a coordinated research effort to increase understanding of road weather phenomena and develop options for increasing safety, mobility, and efficiency of the nation's roadways during all types of weather;
3. improved modeling capabilities and forecast tools designed to provide relevant, useful information to those who build, maintain, operate, and use the nation's roadways;
4. multiple mechanisms for communicating road weather information to the range of users in ways that support better informed decision making; and
5. an infostructure that takes advantage of new technologies to monitor and predict road weather conditions and then effectively convey road weather information to end users.

The report went on to make many detailed recommendations on structuring and implementing a national road weather research program. Of particular note are recommendations to:

- **Establish Regional Centers.** The report recommended establishing regional research centers in order to foster the development of new technologies and their implementation on the roadways, and to facilitate interaction between federal, state and local governments, the private sector, and academia. Because regions share the

same road weather challenges, regional centers are preferable to either individual state programs or a single national center.

- **Create National Demonstration Corridors**. As a means to demonstrate the effectiveness of road weather improvements and facilitate the implementation of research results, the report recommended establishing national demonstration corridors along two U.S. interstate highways, one running north-south and one running east-west. These interstates should traverse areas with diverse climate conditions, topography, and geography in order to address a wide range of road weather conditions within the demonstration corridor. A major objective for these corridors should be for adjacent states to work together to provide a seamless stream of road weather information to users.

SIGNS OF PROGRESS

Some examples of transportation technologies available today which are being used to mitigate weather impacts on road transportation follow:

Dynamic Message Signs (DMS) are silent messengers strategically placed along highways to disseminate time-sensitive information to travelers on traffic flow rates, weather conditions, road closures, and alternate routes. Although this technology has been used for many years, today's signs can now display real-time information received from a remote location. In Finland, such signs are used to adjust posted speed limits according to road and weather conditions.

Vehicle Telematics include a variety of in-vehicle information and communication technologies and services. For example, since 1997, General Motors' OnStar technology has offered drivers the ability to contact live, knowledgeable advisors for assistance if broken down, lost, or otherwise in need of service or information. Other companies are developing similar technology; there could be as many as 12 million telematics users by 2008. Advances in telematics hold promise for improving how weather and traffic information is communicated to drivers.

Intelligent Transportation Systems (ITS), a major focus of the last decade, seek to take existing detection, computer, and communication technologies and apply in them in an integrated way to increase the safety and efficacy of road transportation. For example, in Minneapolis-St. Paul, real-time data from freeway traffic counters are input into freeway capacity algorithms which, in turn, automatically regulate traffic lights at entry ramps to improve traffic flow.

511 is a single telephone number designated by the Federal Communications Commission in July 2000 that will ultimately connect callers to traffic, weather, and road condition information that can be obtained as they travel through different states.

Specific road weather websites have been developed by several states and private firms that display real-time weather, road condition, and traffic information, including pavement temperature, air temperature, wind direction and speed, dew point, precipitation, pavement condition, and subsurface temperatures.

Sensors embedded in the road surface now relay weather, road condition, and traffic data to maintenance personnel and traffic managers. These data can be used to make forecasts, for example, about when road temperatures will reach the freezing point. In some locations, automatic de-icing devices are coupled with the temperature sensors so the devices will spray an anti-icing chemical on the road when it reaches freezing and water is present.

THE CANADIAN SCENE

The US National Research Council study brought together an imminently qualified group to propose elements required to advance the science and application of road weather in the United States for the benefit of their citizens, their environment and their economy. The group included well known researchers and practitioners from the transportation community including winter maintainers and from the meteorological community including road weather service providers. As mentioned early, the group received numerous briefings and a large amount of reading material. The report findings therefore merit close consideration.

That said, the differences between the US and Canada must be borne in mind. Canada will be much less affected by tropical storms and hurricanes but much more affected by winter weather phenomena for example. Canada also has a greater rural content to its road networks. An examination of each of the five main report recommendations is certainly warranted.

The first recommendation, a robust integrated observational network and data management system specifically for road weather research and operations, is actually already very well engaged in Canada. Indeed, the provinces got together in April 2000 and unanimously agreed that a national integrated network of road weather stations would benefit our country. A Road Weather Information System (RWIS) for Canada proposal was prepared, reviewed several times, and supported by the Canadian Council of Deputy Ministers Responsible for Transportation and Highway Safety. The federal government responded favourably. Transport Canada (TC) announced in August 2003 that it would be willing to enter into negotiations with provinces for the co-funding of RWIS systems leading to a national integrated network along the national highway system. Environment Canada (EC) announced in March 2003 that it would provide data quality control and management services to integrate the RWIS Canada data. Most provinces are currently negotiating contribution agreements with TC and data sharing agreements with EC and many have already completed or are planning provincial RWIS networks. Significant work has therefore already taken place in Canada to deploy a

robust integrated quality observational network and data management system for road weather research and operation.

The second recommendation was a coordinated research effort to increase understanding of road weather phenomena. A number of efforts are underway to address some of the more pressing issues in Canada. The Meteorologocial Service of Canada (MSC) developed a road condition forecasting model, METRo[1], several years ago. TC recently approved funding from their portion of the Program on Energy Research and Development (PERD) fund to improve and enhance METRo. The MSC will match that investment to rewrite the METRo code into a portable format and prepare user and licensing documentation to transfer METRo to private sector firms interested in providing road weather forecast services. TC's Transportation Research Centre is currently pursuing a study on variable load restrictions, frost effects on road infrastructure – a very important consideration for Canada. Some provincial transportation ministries are also studying the use of RWIS station surface and sub-surface temperature probes to trigger springtime load restrictions, to minimize damage to the road infrastructure at the time of the year when it is most susceptible. The Transportation Association of Canada has approved a project to develop a winter severity index for Canada. Researchers from the MSC, McGill, UQAM, and York universities are currently working on a proposal to develop and test a prototype winter road weather forecast system based on a high resolution regional version of the Canadian operational weather prediction model, and the nowcasting (very short term forecasting) of snow using weather radars. Other research efforts are also likely being pursued in the area of road weather, winter maintenance and decision support systems. Still there is no source of sustained funding or leadership for a robust, coordinated research program. This is a serious deficiency given the weather impacts on road transportation in Canada.

The third recommendation was improved modeling capabilities and forecast tools designed to provide relevant, useful information to those who build, maintain, and use roadways. The MSC operates a supercomputing facility in Dorval and deploys significant resources to constantly refine and advance its modeling capabilities. The Global Environmental Multiscale model, the main operation numerical weather prediction (NWP) model, should be running at a sub five kilometre resolution within a few years. This will resolve very well the future state of the atmosphere for road weather applications – particularly for highway systems. Finer resolutions would still be required for large metropolitan centres. What will be lacking however will be efforts to develop tools to apply these NWP model outputs to provide relevant, useful information to those who build, maintain, operate, and use the roadways. While some of this certainly will come from academia and the private sector, a more coordinated approach and some funding would certainly be advantageous.

[1] Crevier, Louis-Philippe and Yves Delage, Journal of Applied Meteorology of the American Meteorological Society, November 2001 pp 2026-2037 METRo: A New Model for Road Condition Forecasting in Canada.

The fourth recommendation was multiple mechanisms for the communication of road weather information to the range of users in ways that support better informed decision making. This is principally the responsibility of the transportation community and of the private sector. However, significant and sustained coordination would certainly be beneficial. In that vein, TC has developed the Intelligent Transportation Systems Architecture for Canada which should serve as an excellent planning tool for the communications required in the road weather area. In fact, in adapting the US ITS Architecture for use in Canada, one of the main areas of adjustment was to better integrate road weather information and services. With this architecture in place, industry will be able to respond with the needed business models and delivery mechanisms as technology advances.

The final recommendation was an 'infostructure' that takes advantage of new technologies to monitor and predict road weather conditions and then effectively convey road weather information to end users. The monitoring aspects, at least for the provincial highways, will be largely addressed by the RWIS Canada proposal that the provinces brought forward several years ago and is now begin strongly supported by TC and EC. It is anticipated that the private sector will step forward to address municipal monitoring requirements. While the MSC will continue to deploy significant efforts to model and predict the atmosphere, the application of the future weather conditions to predict future road weather and resultant road conditions will be the domain of the private sector in Canada. They most certainly will make research investments as will academia. However, contributions from the federal and provincial levels of government and some overall coordination would certainly benefit Canadians. The last part of this recommendation, the conveyance of road weather information to users, will be the domain of provinces and municipalities who will in turn doubtless engage the private sector.

RECOMMENDATIONS FOR CANADA

Canada is already very well along in the deployment of a national integrated road weather network. The provinces are to be commended for their foresight in this area and TC and EC for supporting this initiative. The RWIS Canada network will provide a rich quality road weather data base for the transportation community and the Canadian private sector to deliver highly sophisticated road weather applications and services to Canadians. Considerable research and development will be required. Some R&D on pressing issues is currently being pursued and hopefully this will continue. What is desperately needed is leadership and sustained funding to ensure that the maximum benefits are achieved from the RWIS Canada investments and to ensure that academia and the private sector in Canada can play leading roles in the development of road weather forecasting and information dissemination applications. It is respectfully suggested that that leadership, including on efforts to secure sustained R&D funding, should come from TC and EC. The benefits to Canadian motorists, our environment and our economy would be enormous.

CREDITS AND CONTACTS

Much of the US section of this paper was drawn from a brief report prepared **by the National Research Council and is based on the committee's report. More information can be obtained by** contacting the National Research Council's Board on Atmospheric Sciences and Climate at (202) 334-3512, or the Transportation Research Board at (202) 334-2934, or the author of this paper. *Where the Weather Meets the Road* is available from the National Academies Press (www.nap.edu.), 500 Fifth Street, NW, Washington, DC 20001; 800-624-6242.