ROAD WEATHER INFORMATION SYSTEMS
A NEW DATA SOURCE?

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INTRODUCTION

As far back as 25 years ago, sensors were developed to determine the temperature and condition of road surfaces. Unfortunately, not a lot was known (or thought) about the road environment and sensors were not wisely placed. Also, the early sensors were unreliable. In the last 15 years or so, a great deal of effort has gone into developing reliable sensors.

Along with, and in some cases paralleling sensor development, (far-sighted) meteorological practitioners and road authorities recognized future knowledge of the weather and perhaps more importantly road conditions, might allow snow-and-ice control decision makers to do their job better.

I'm happy to report that because of the work of a few individuals in both camps, the technology is here. We are seeing a new term ... Road Weather Information Systems (RWIS). What is the RWIS technology, who can use it, and why should anyone use it? This paper will describe the role of a Strategic Highway Research Program (SHRP) project which was designed to answer those questions. Following an introduction to SHRP, the project's objectives will be presented. Next, the paper will describe the current project status, including findings to date, future work, and products to be delivered will be discussed. Finally, other research will be discussed.

BACKGROUND

The Strategic Highway Research Program

In the 1987 Highway Act, the Congress of the United States authorized the expenditure of $150 million for the Strategic Highway Research Program (SHRP). SHRP is administered by the National Research Council under the National Academy of Sciences.

SHRP is conducting research over five years in four specific areas: asphalt, concrete and structures, long-term pavement performance, and highway operations. In highway operations, research is concentrated primarily in improving maintenance cost-effectiveness and snow-and-ice control. Research is being conducted in support of highway operations to investigate technologies to help reduce costs in snow-and-ice control through more efficient and timely assignments and uses of resources.

The Storm Monitoring/Communications Contract

In 1988, the Strategic Highway Research Program (SHRP) entered into an agreement with the Matrix Management Group to investigate the use of weather information to assist highway maintenance people. The thesis is that if snow and ice control decision makers use weather information to their advantage, i.e., be proactive in using weather information in their decision processes, they can allocated resources more effectively and more efficiently. This may lead to reduced costs and improved service to the traveling public.

The objectives of this contract, SHRP-87-H207, entitled Storm Monitoring/ Communications, are to:

- o identify the most promising approaches for improving the capabilities of snow and ice control organizations for making rapid and cost-effective responses to winter maintenance requirements, with minimum inconvenience to the public, and with maximum public awareness of road conditions; and
- o rank the potential payoffs, costs, and cost-effectiveness of the various approaches, and to validate the best approaches by field trials.

The contract is a three-year study. Products produced from this study have included a benefit-cost methodology; a document suggesting guidelines and strategies for road weather information system communications; and an interim report at the conclusion of the first year. Remaining products to be developed include a document which will provide guidelines for siting pavement and meteorological sensors, and a document which will provide guidelines on selecting appropriate types of weather information for highway snow and ice control decisions.

For the past year and a half, we have been gathering information on the use(s) of weather information for snow and ice control operations on highways. We conducted literature searches, sent questionnaires to all states and provinces of Canada, and conducted in-person interviews. All of these have provided the basis for determining the uses of weather information for highway maintenance snow and ice control decision makers. The key forms of road and weather information include weather forecasts, observations and sensor data, and judgement arising out of meteorologist-highway decision maker interaction.

We also developed a benefit-cost methodology in order to rank the various options. The methodology will be a simulation in which specific maintenance practices and weather phenomena will be used with and without the benefit or weather information for the decision makers. Real examples for inclusion in the model will come from state highway agencies with whom we've been working.

The following products have or will be delivered as a result of the contract.

- o Guidelines & strategies for RWIS communication (in draft)
- o Guidelines for placing and locating sensors (draft due this fall)
- o Guidelines for implementing RWISs (draft due this fall)
- o A contract Final Report due in September 1991.

During the 1990-1991 winter we will also be conducting field tests which we have designed in order to verify, validate or complete our research. Tests will be conducted in Minnesota, Colorado and Washington. A heavily instrumented section of Interstate 94 northwest of Minneapolis will be used as testing site for determining where pavement sensors should be placed in the roadway . The site has eight Vaisala pavement sensors placed in four lanes: two asphalt eastbound and two concrete westbound, each lane having a sensor in the wheel track and in the center of the lane. In addition, subsurface thermistors and thermocouples are installed at 21 depths down to 12 feet in two locations. Minnesota also has an SSI SCAN system installed on the I-35 bridge over the Mississippi river, has thermally mapped roads in the Duluth area, and is looking at installing more sensor systems, including a freezing point sensor recently announced as available. A representation of the Minnesota road test sensor installation system is shown in Figure 1.

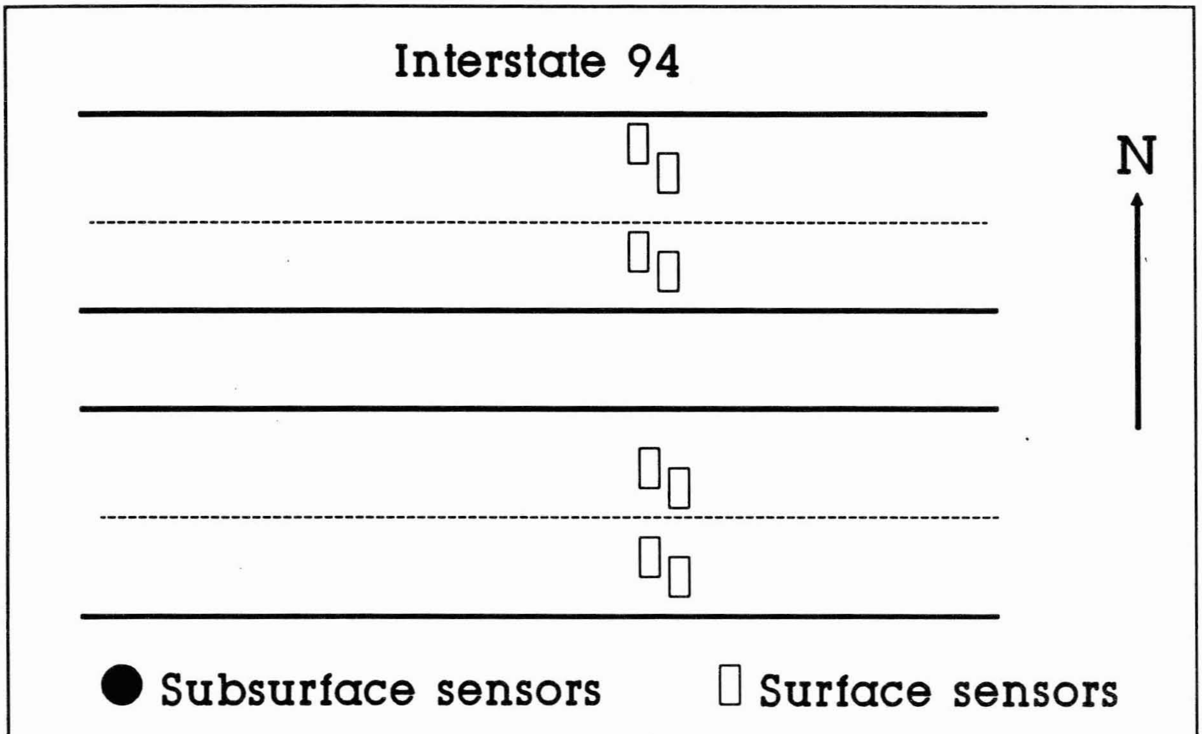

Figure 1. Minnesota test representation

The Denver, Colorado area is also of interest because it, too, is heavily instrumented with pavement and meteorological sensors, some owned by the City, mostly the Department of Highways. A total of 14 SSI pavement sensor locations, 12 with meteorological sensors, will help us identify the best spacing between sensor locations. Especially noteworthy is that Mr. Gordon Bell, a Colorado maintenance superintendent, has maintained a log for a year now of weather and pavement conditions, forecasts, and decisions he's made based on the information. He has also attempted to record the decisions he would have made had he not had the sensor systems and forecasts. Finally, the northeastern corner of Colorado is also very heavily instrumented for meteorological research purposes. There is the possibility of determining the utility of RWIS data to the meteorological community,

Our third state, Washington, recently installed four SSI sensor suites in one area of a maintenance district. The area includes Metropolitan Seattle and covers about 200 mi.[2] Of particular interest, the state roads in this area, ranging from 2-lane rural to 12-lane urban freeway, were thermally mapped to develop thermal fingerprints for the roads. These thermal fingerprints are being used in conjunction with pavement temperature and condition forecasts to provide forecasts of the same for the entire road network rather than one site. We will be evaluating the validity and utility of this capability. Washington also has three sensor systems installed in the I-90 mountain pass area East of Seattle. These have been in place for a number of years and are going through an upgrade to the latest generation of sensors this Spring.

In all of these locations we will also be gathering response data and costs to use to verify the benefit-cost analysis. Each of the states uses different maintenance practices--Minnesota uses salt; Washington uses very little and, in fact, is going to only non-corrosive additives to sand. Colorado (urban Denver) uses up to about 18% salt/abrasive mixture.

CURRENT STATUS

We just completed the preparation of a Test Plan which describes in somewhat more detail the field tests we intend to conduct next winter. We are working on two seemingly separate, but in reality important issues which we believe are crucial to helping you as planners or operators in acquiring or using RWISs.

Currently we are wrestling with the issue of establishing standards for RWISs. This is an issue for the following reasons. First, if it is deemed advantageous for meteorological data from RWISs to enter the Federal meteorological system, it is written that the data must come from systems which meet Federal specifications, either Federal Aviation Administration or National Weather Service specifications. At this point we believe it would be sufficient for RWIS installations to meet either specification, preferably the latter. Second, standards make it easier for you, the purchaser. There is no reason every one (or even two different entities) should have to write a specification to purchase something in which yo have no expertise. Third, as it stands right now, an RWIS acquired from one manufacture won't work with one from a different manufacturer. Each purchaser is forced to make a decision on which system to go for. This decision could impact neighboring jurisdictions, as well. A communications standard could at least preclude such difficulties. Finally, it is an issue in the vendor community who have legitimate concerns over the formulation of specifications and the possible impacts on their work.

Next, we've noticed problems some agencies have had in procuring meteorological services. There is a tendency in the maintenance community to buy weather services just like sand and gravel are purchased: from the low cost bidder. This is forcing the purveyors of weather services into bidding absurdly low prices for professional services. It is also allowing perhaps less-than-desirable quality of services to win contracts. Unfortunately the customer, you, is getting what you pay for. We also believe too many agencies are not sure what kind of services should be acquired. We intend to suggest contracting guidelines for public agencies to use when contracting for weather services. Of course, cost should be a consideration; but so should technical and professional competency.

FINDINGS TO DATE

- Probably the most pervasive finding our team has encountered is that snow and ice fighters are a truly devoted, dedicated group of people. Some of them live for winter, for driving the snow plow, for helping the public. Some of them also like the overtime and may not take too kindly to programs like ours which are looking at ways to reduce costs. And overtime pay is a big player.

- The cost of snow and ice control to the various agencies in the United States is about $1.5 billion per year. This figure is primarily the direct costs for labor, equipment and materials on the road doing snow and ice control. The agencies, in general, do not add costs of cleaning up the roads, supervision, planning, etc. Also, there is no good figure for the indirect costs (benefits) of snow and ice control, i.e., the societal costs (benefits) due to improved transportation, commerce, accident rates, insurance losses,. etc.

o The use of meteorological and pavement sensors for snow and ice control in this country is not commonplace, but is increasing. Individual states have used Federal Highway Administration (FHWA) experimental funds or their own to test ice detection systems. Some cities and counties have done the same. Especially interesting are the joint or interagency cooperative ventures. Examples include cost and data sharing initiatives in the Kansas City, Kansas area with Kansas and Missouri Departments of Transportation (DOT); St. Louis, MO and the Missouri DOT; a council-of-government initiative in the Washington, D.C. area; a city, county, state DOT, and airport venture in Spokane, Washington driven by meteorological impact concerns over a municipal waste combustion facility; Denver, Colorado and Chicago, Illinois.

We have always argued the notion that the weather doesn't care about political boundaries. Although we have not zeroed in on an ideal siting density. In figure 2, however, a representation of city, county, and state roads shows how cooperation can enhance a network of sensors. One agency doesn't have to foot an entire bill, but all can benefit.

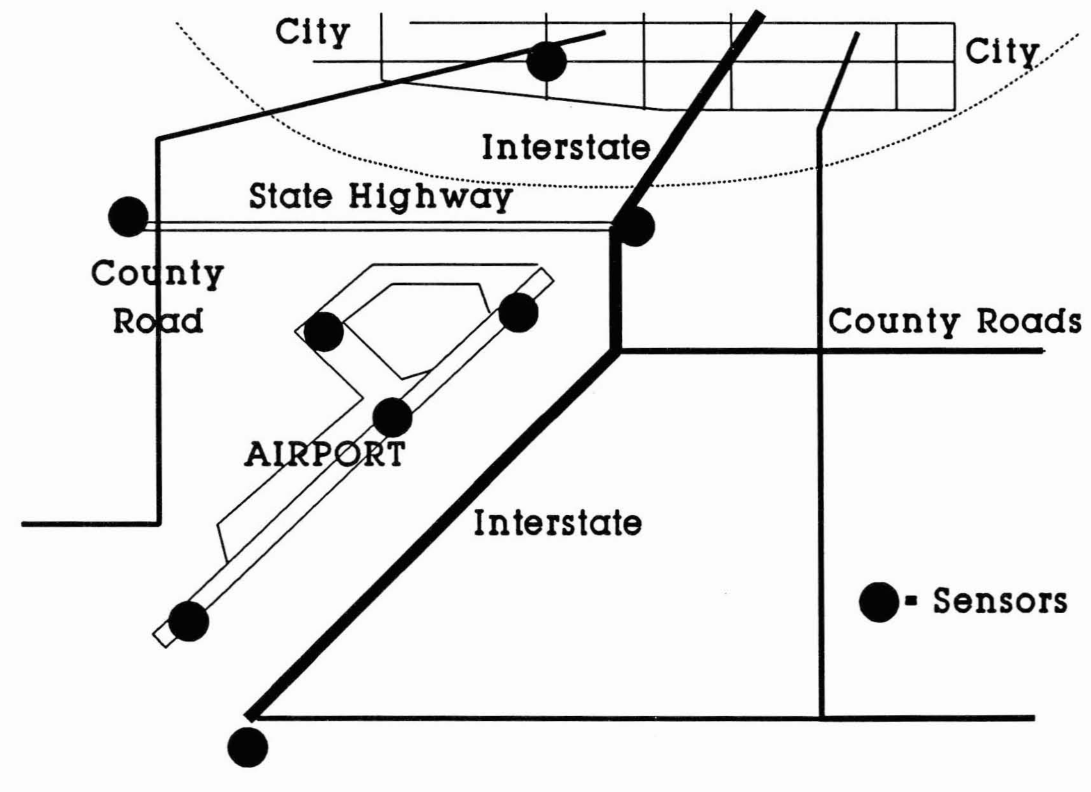

Figure 2. Example of interagency cooperation.

o Thermal mapping, mentioned earlier, is an intriguing concept that requires evaluation. The concept behind thermal mapping is that if one knows the thermal fingerprint of a road system under certain conditions, then if one knows the temperature at one point under similar conditions, one then knows the temperature everywhere. This is suggested only for the early morning (coldest) parts of the day.

Temperature profiles are obtained by driving instrumented vehicles over a road network under different atmospheric (sky) conditions: clear sky, low-middle cloud overcast, and in rain. Theoretically, the profiles can be used to identify locations for sensor installation. It is argued that for predictive use of weather information, typically always cold and always warm (relatively) locations are desired, as well as some typically average locations. It is also argued that salting and plowing routes can be devised using the thermal maps. For example, one could set up routes to salt coldest roads first and warmest second.

o The most promising way to save money at snow and ice control appears to be to be proactive in using RWIS information, namely weather and pavement condition forecasts. Presalting, pre-emptive salting, or anti-icing are all words that describe a proactive technique. It takes 1/5 to 1/10 the amount of salt to prevent ice as it takes to melt ice (deice).

This is the reason for an ice prediction system. A detection system is reactive. A prediction system is proactive. One highway engineer I interviewed said his philosophy is "just-in-time maintenance." Get the plows out "just-in-time." Get the salt down "just-in-time." You can only do that with forecasts.

o Forecast technology is getting better. Computer models continue to improve and their resolution continues to increase. Data grids of about 10 mi (15 km) are within reach. Model outputs combined with reasonable terrain fields will make temperature precipitation, and cloud cover forecasting much easier.

The key to your work, though, is pavement temperature. If ice or frost are to form, or snow stick, it's a result of pavement temperature, not air temperature. Therefore you need reliable pavement temperature forecasts. Based on our interviews and literature in hand, about 90% accuracy can be expected in pavement temperature forecasts. This is for forecasts issued the afternoon before, say at 12:00-3:00 p.m. for 6:00-8:00 a.m. We have conducted no forecast verification analysis but intend to next winter.

It should be noted, however, that there are two types of possible errors: one is "bad"; the other is "very bad". Figure 3 shows a typical decision matrix. One wants to maximize the "good" situations where, for instance, frost occurs and action was taken, or the forecast called for no frost and no actions was required. The "bad" type of situation occurs when frost is forecast (but doesn't occur) and crews are dispatched. This would waste resources. The worst situation is to have no forecast of frost (it does occur) and no maintenance action was taken. This can lead to accidents. These types of errors need to be minimized. However, minimizing these errors tends to lead to pessimism in forecasts and overforecasting of frost. Research in England is looking at techniques to minimize the "very bad" forecasts without increasing the percentage of just "bad" forecasts.

o Work is moving forward on at least two fronts on developing "expert" systems for helping make resource allocation decisions for snow and ice control. Separate efforts by people at Utah State University and by Dr. Elmar Reiter, of Wels Research, Inc. in Colorado, and who is also being funded by SHRP, are the two known examples of work going on in this country. The purpose of the expert systems, I believe, are to help in the assimilation of information in an orderly fashion to help a decision maker. One of the problems we face in an increasingly information-oriented environment is how to sort out the information that is important. For your purposes, the information your need involves current road and atmospheric conditions, forecasts of same, the types of maintenance activities your perform, and your resource availability (shift schedules, vehicle readiness, etc.).

Action (Based on forecast)	Actual Weather: Frost	Actual Weather: No Frost
Treat	Good	Bad
Don't Treat	Very Bad	Good

Figure 3. Weather Decision Matrix

o Probably not unknown within the maintenance community, but not well recognized in the meteorology community, snow and ice control practices vary considerably from one area to another based on attitudes as well as weather patterns. Some areas use a lot of salt, some use prewetted salt (with liquid calcium chloride or water), some use only abrasives, some use mixes of salts and abrasives, and some use mixes of "exotic" chemicals (those that are either non-corrosive or non-chloride based), some use exotic chemicals only, etc.

The important thing to recognize is that in terms of their most effective or efficient use, each of the above practices is impacted perhaps differently by the weather. And especially in terms of anti-icing, unless one uses a wetted salt, it's tough to make an application prior to frost formation that will remain on the roadway to prevent the frost.

It was very interesting to learn that in England, where a National Ice Prediction System has been developed, the salt used by the road authorities there is very different from most, if not all, of our salt. Their salt is very hygroscopic, and contains at least five percent moisture. I'm told at 80 percent relative humidity, it goes into solution. They have naturally pre-wetted salt and it is ideal for anti-icing.

OTHER SNOW AND ICE CONTROL RESEARCH

Strategic Highway Research Program

Six other SHRP contracts have been let relating to snow and ice control. Two are fundamental studies dealing with pavement and ice bonding, one with Brooklyn Polytechnic University looking at the ice-substrate bond structure and the mechanics of formation in order to prevent bond formation without adversely affecting desirable pavement properties, such as friction. Another is with Midwest Research Institute and is centered on the ice-substrate bond from the point of view of disbanding in order to provide a sound basis for developing techniques and devices for disbanding ice *after* it as formed on a pavement surface.

Two contracts were separate efforts based on the fundamental research described above. The first, with Springborn Material Sciences, Inc., is investigating methods for concentrating a deicing chemical or chemicals on or near the surface of pavements which will effectively reduce snow/ice adhesion at low temperatures. It will also involve developing a method of physically modifying pavement to prevent formation or bonding of ice. The second contract, with Michigan Technological University's Institute of Snow Research, has three main tasks. The first is to develop a pavement physical modification that is economical, long-lived, effective over a wide range of conditions, relatively easy to incorporate and maintain, and provides an adequate coefficient of friction. Second is to investigate methods of applying energy at the ice-pavement interface to achieve disbanding without direct contact with the pavement, and to develop a prototype device to achieve the disbanding. The third task is will investigate methods of separating ice frozen on pavement by use of a contacting device in order to improve mechanical efficiency and reduce wear and damage to equipment and pavement.

The last contract mentioned above will have to coordinate with another contract with the University of Wyoming Department of Mechanical Engineering which is working on a two-phased effort to improve displacement plows and blowing snow control. The first phase will establish design criteria and prepare specifications for displacement plows based on aerodynamic/hydrodynamic principles, material handling characteristics of snow, and ice cutting mechanics, leading to standard designs for different types of snow and climatic conditions. The second phase will methods for reducing the amount of snow reaching a roadway, to include design and/or location of roads, overpasses, guard rails, and vegetation. It will also include the developing of improved methods for controlling blowing snow and refining design criteria for reducing snow drifting on highways.

Finally, the Midwest Research Institute was awarded a contract to establish criteria for evaluating deicing chemical effectiveness, characteristics, and impacts, and to develop standard procedures for monitoring and testing. This contract will also look at reducing the deleterious effects of salt and improving its ice-melting properties.

Other Research

Some research is being sponsored by the Federal Highway Administration (FHWA). This includes an Experimental Project No. 13 which is collecting data on the uses of weather information in dispatching resources. Some of these data will be used by us. The FHWA also funds experimental projects in many states on the use of weather information. The states, however, generate the project and seek federal funds.

Much of the research is being conducted by the states, themselves. The three states mentioned above are good examples of the efforts being put forth by the states. We are also aware of research into alternative deicers being conducted in other states, too. Michigan uses CMA only on the Zilwaukie bridge near Saginaw. Through the use of their SSI system, they have been able to reduce the CMA amounts required by 50 percent. Massachusetts is conducting alternative chemical research primarily due to water/aquifer contamination. Washington has recently decided to go strictly to alternative chemicals and forego the use of salt completely.

Some of the most interesting efforts are those underway in multi-agency ventures. A few examples were given above. In addition, the APWA Research foundation has recently announced a research project which will look at the use(s) of the road weather technology in cities and counties. The Research Foundation will be surveying the public works community to project sponsors and for Project Advisory Committee members.

The interest in the RWIS technology level from the Strategic Highway Research Program, the Federal Highway Administration, the American Association of State Highway and Transportation Officials, and now the American Public Works Association points to the potential help to the snow and ice control community, to the road users, to the taxpayer in general, and to the environment. Those of us who have been associated with the technology in one way or another, represented in this forum, certainly believe in the potential. And we, in particular, believe that the effort we are working on for the Strategic Highway Research Program will have benefit for all public works agencies.

In closing, it should also be pointed out that even though this research is focussed on snow and ice control activities, there are indications that significant cost reductions are also possible through the use of weather information on a year around basis for both roadway maintenance and construction activities.