Road Weather Information Systems: What Are They and What Can They Do for You?

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Road weather information systems (RWISs) have been implemented operationally or tested in many states, counties, and cities, both in the United States and internationally. Research conducted for the Strategic Highway Research Program determined that RWISs can help highway agencies to optimize the resources allocated for snow and ice control. Questionnaires were sent to all of the states and the provinces of Canada; interviews of snow and ice control managers were conducted in 11 states and one Canadian province; and field tests were conducted in Colorado, Massachusetts, Michigan, Minnesota, Missouri, New Jersey, and Washington. The various RWIS technologies are described: meteorological and pavement sensor systems installed in the road environment; road thermography, which involves constructing thermal profiles of road segments using vehicle-mounted infrared thermometers; and detailed, site-specific weather forecasts provided through interaction with meteorological service providers and information tailored to the highway agencies' needs. In addition, the communications aspects of providing information effectively to highway agencies are discussed. Experiences, primarily in Colorado, Minnesota, and Washington, are highlighted, including anecdotal information gathered from other state agencies through interviews and field tests. Successful interagency cooperative efforts are also described because of their ability to reduce the costs of acquiring RWIS hardware for each agency through cost sharing. Finally, cost analysis results of the research are highlighted to point out the potential cost reductions for highway agencies that implement RWIS technologies.

Road weather information system (RWIS) is a term that encompasses the sensing and collecting of on-site weather and road condition information, the processing and dissemination of the information, and the creation and dissemination of forecasts of road and weather conditions. It also refers to people. Some of these people are the meteorologists who issue forecasts and interact with highway agency customers. RWISs are currently installed for use by many states and other agencies to assist in the management of snow and ice control.

In 1988 the Strategic Highway Research Program (SHRP) initiated Study H207 (Storm Monitoring/Communications) to investigate the uses and cost-effectiveness of RWIS technologies. The research team members included the Matrix Management Group, Seattle, Washington; the Washington Transportation Center at the University of Washington, Seattle; and the University of Birmingham in England.

Information gathered in the project showed that more than $2 billion is spent each year in the United States and Canada on snow and ice control. It is believed that some of this money can be saved by using RWISs. This paper briefly describes the H207 research project, identifies different RWIS technologies, and describes some of their uses. Finally, it presents the results of the research.

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RESEARCH

The H207 project can best be described in phases: initial information gathering, field testing, and analysis. Gathering information involved sending questionnaires to all of the states and to the provinces of Canada to ascertain the extent of use of weather information and equipment in support of snow and ice control. Questionnaires were also sent to manufacturers of meteorological equipment to define the state of the art in sensing weather and pavement conditions, and to meteorological service providers to determine the types of services available and level of support being provided to highway agencies.

In addition to the questionnaires, the research team conducted interviews in 11 states and one Canadian province. The purpose of the interviews was to determine the types of snow and ice control activities being conducted, the types of weather or road condition information that could assist decision makers, the types of management systems in use for allocating snow and ice control resources, and the types of resources—labor, equipment, and materials—used in snow and ice control.

A literature search was conducted to define the body of knowledge related to RWISs, especially to snow and ice control support. Although initially little published information was produced in the United States, a great deal of information was available from Europe through European cooperative research efforts with support from governments and manufacturers of RWIS technologies. The results of the search are presented in a large bibliography in the H207 final report.

Field testing was conducted to evaluate the use of RWIS technologies in different climates and for different maintenance practices, and to assist in establishing the cost-effectiveness of RWISs in support of snow and ice control maintenance. Initially, tests were to be conducted in Colorado, Minnesota, and Washington. Because of the potential of having few winter weather events in only three states for one winter, four more states were enlisted: Massachusetts, Michigan, Missouri, and New Jersey. Even so, for reasons ranging from broken RWIS equipment to few winter weather events, only

75 winter weather events, and comments about the RWIS use in support of snow and ice control operations, were reported from the seven states.

Finally, a cost analysis was conducted to evaluate the cost-effectiveness of RWIS technologies in support of snow and ice control. The team developed a computer simulation model that produced ratios of reduced costs in snow and ice control compared with the costs of various weather information sources. The model used statistical techniques to assess the cost reductions in snow and ice control, the ability of weather information to reduce decision errors, and the ability to improve the service level of snow and ice control to the roads.

Only direct benefits—the reduced costs of labor, equipment, and materials—were considered in the analysis. It is believed that the indirect benefits, such as reduced accidents, fuel consumption, insurance premiums, and losses to commerce, will increase the reductions in cost, or benefit-cost ratio, resulting from using RWIS data.

RWIS TECHNOLOGIES

Pavement sensors are probably the most recognizable technology because of usual references to such devices when referring to RWISs. In fact, the terminology of pavement sensors and RWISs appears almost interchangeable to some. But even though a pavement sensor is an extremely important component of an RWIS, it is only one of several.

Pavement sensors typically measure pavement temperature, the condition of the pavement surface (e.g., wet, dry, ice- or snow-covered), and the concentration of deicing chemical on the pavement. Passive sensors use resistance measurements for temperature, and combinations of surface conductivity and field capacitance for the other determinations. Not evaluated during this project is a more recent technology that uses an active sensor to determine the temperature at which the (wet) pavement surface would freeze.

Pavement sensors can be located in the roadway surface for either detection or forecasting of pavement temperature and conditions. It is suggested that predictive siting be the primary purpose for siting sensors since predictive information is most useful in making decisions to assign snow and ice control resources in a timely and effective manner. If sensors are installed for prediction, a subsurface sensor is required to measure the temperature, usually about 0.5 m (20 in.) below the pavement surface in order to determine if heat is flowing toward or away from the pavement surface.

Pavement sensors have many uses for snow and ice control. The pavement temperature can be used to validate pavement temperature forecasts, to determine whether ice formation or bonding can take place, and in turn whether deicing or plowing may be necessary. However, these decisions are best made by using forecasts of pavement temperature and being ready for action, rather than by waiting for conditions to occur. Changes in pavement condition, such as from dry to wet and from wet to ice-covered, are important thresholds for alerting managers that action is required. The chemical concentration of deicing chemicals is a key indicator of whether an application of deicing material will be required or not. If a concentration is above a certain threshold (material dependent), a manager may elect to forgo an application even with a pavement temperature below 0°C (32°F) and wet pavement. The chemical factor can also be used to determine if and when maintenance has made an application of the road where the sensor is located.

Atmospheric sensors and pavement sensors should be collocated. The atmospheric sensors provide additional important information for making decisions and for forecasting weather and pavement conditions. The combination of sensors, their installation, and power and communications hookups are usually referred to as remote processing unit (RPU) stations, RPUs, or outstations (in Europe).

A typical set of meteorological instrumentation at an RPU station would include an anemometer for wind speed and direction, a thermometer and hygrometer for air temperature and dewpoint, and a precipitation detector. Additional sensors can provide information on visibility, amount and type of precipitation, incident and net radiation, and water level if stream gauges are installed. In the future, it is possible that more sensors, such as air-quality monitors (perhaps in transportation nonattainment areas), soil moisture probes (to assist with frost heave analysis), and snow-depth detectors, will be a part of RWIS installations.

Like that of pavement sensors, the most important use of atmospheric sensors is to assist in the prediction of weather and pavement conditions. Data from the sensors are introduced into forecasting models or are used as a basis for initiating forecasts. Data are also useful in helping make decisions about snow and ice control. Examples of data use include wind direction and speed for drifting snow and "freeze drying" of roads (relates to the need to plow), sunlight to melt snow (for making chemical applications), and falling temperatures and dewpoints in conjunction with pavement temperature (to worry about frost).

Road thermography, a technique developed in Europe, involves driving an instrumented vehicle over roads, measuring the pavement temperature with an infrared radiometer, creating profiles of pavement temperatures related to distance along a road, and noting important road and terrain features. The profiles are usually constructed under different atmospheric conditions, because of the different radiational responses of pavement under cloud cover or clear skies, and different precipitation and wind conditions. During the H207 investigation, thermography was accomplished using a handheld radiometer. Although the measurements of pavement temperature in either case may not accurately measure pavement temperature, they do represent relative temperature differences, which are what is important.

Very little thermography has been conducted in the United States, and little use has been made of what is available. In Europe, thermography has been used to assist in selecting RPU station locations, developing forecasts for pavement temperature over a road network by using the profiles to fill in the gaps between sensors, and establishing staged response to snow and ice needs on the roads. For instance, if the forecast calls for only a small portion of roads to be below 0°C (32°F), then a manager may need to call out only a small crew. In Vancouver, British Columbia, the route priorities of snow and ice plows were changed on the basis of the profiles to ensure that the coldest road segments are plowed first, the warmest last.

Meteorological data are another component of RWIS technologies. Examples include weather radar or satellite data, weather observations and forecasts, and maps of meteorological parameters that can be provided to decision makers, especially the data due to be provided by the Next Generation Weather Radar (NEXRAD) currently being installed by federal weather agencies. NEXRAD will have the capability to create maps of projections of precipitation patterns and accumulations overlaid onto maps with road networks and geopolitical references. It is expected that these products will be extremely useful for meteorologists and highway maintenance people alike.

Communications is a major and vital component of an RWIS. Communications are required to disseminate sensor and forecast information to managers and meteorologists. The major components of communications include

- Sensors to RPU, usually hard-wired with cable;
- RPU to a central processing unit (CPU), either via telephone or radio;
- CPU to snow and ice control decision makers and managers, through a collocated or remotely located computer work station or portable computer;
- CPU to meteorologists via remote computer connections;
- Meteorologists to snow and ice control decision makers, employing many means, but normally computer-to-computer connections, telephone facsimile, or direct voice contact via telephone; and
- Perhaps some method of communicating road information from an RPU to the traveling public, such as variable message signs, but this is rarely done in the United States.

Sometimes considered a part of communications, RWIS data processing is an important component of a system. The processing involves formatting raw sensor data into usable information for decision makers or meteorologists and graphical displays of data for decision makers. The way that information is presented can directly affect its utility or use. In some cases, data are formatted for use in forecasting models.

Data should also be archived in some form. Archived data can be used for monitoring trends, creating historical files for maintenance record purposes, expanding climatological data records, and developing local area forecast studies.

Forecasting of weather and pavement conditions may be considered the most important part of RWISs. Although not always a component, forecasts provide the capability to make the decisions to get the right resources to the right place at the right time.

Typical sources of forecasts include the public media, the National Weather Service (NWS), and value-added meteorological services (VAMSs). For the types of decisions snow and ice control requires, forecasts from a VAMS are usually necessary since the most valuable information is that which is tailored to the needs of the highway agency. These forecasts are usually beyond the responsibility of the NWS. In addition, pavement temperature and pavement condition forecasts typically require a VAMS.

The final component of an RWIS is the establishment of a consultancy arrangement between a meteorologist and the highway agency. This arrangement is crucial so that each understands the needs and capabilities of the other. Such a role can be filled by a consultant, a VAMS, an RWIS vendor, or a member of the agency staff.

RESULTS

The following section describes the results of the RWIS cost analysis and the utility of RWISs for snow and ice control. It also presents results obtained from interviews and the project's field trials during the 1990–1991 winter. Fewer data than desired were obtained from the field trials because of the mild winter weather. In the event that quantitative data were not available, additional interviews with state highway agency personnel were used to document at least qualitative results.

Cost Analysis

The research team developed a computer model in order to determine the cost-effectiveness of RWISs. The model, described by Boselly (*1*), computes the cost reduction in snow and ice control when decision makers use different RWIS technologies. The cost analysis showed that when decision makers use weather information to their advantage rather than react to conditions, they can make more timely and efficient use of resources. In general, the model showed that

- RWISs are cost-effective. A system that includes all of the RWIS components can reduce the costs of snow and ice control at a ratio of up to 5 to 1 over the cost of the RWIS. If many sensors are installed in an area, though, the ratio is reduced.
- The largest return on the investment results from using detailed, site-specific forecasts of weather and road conditions, because forecasts are relatively inexpensive when compared with the costs of snow and ice control. Practically any reduction in maintenance costs quickly exceeds the costs of forecasts.
- The model also looked at the service level to the roads for snow and ice control. Using RWISs can improve the service level, mainly by allowing decision makers to get the proper resources where they need to be when they need to be there, rather than after the fact.
- RWISs also help reduce decision errors, both by reducing the number of costly errors (Type II: a condition that is forecast does not occur, but resources have been assigned) and the number of dangerous errors (Type I: a condition occurs that is not forecast, and no resources are assigned to treat it).

Decision Assistance Through RWISs

One of the most cost-effective uses of RWISs is to reduce the need for night or safety patrols. Such patrols have been used in some areas for years to look for snow and ice problems. When problems are encountered, maintenance forces are called out. This is a reactive process, and often when the forces are finally on the road, they are behind in treating conditions. Forecasts of pavement conditions requiring treatment offer the opportunity to call out forces when and where they are needed. The (high) costs of patrols are avoided, and the costs of treatment are reduced.

The critical information needed is what the pavement temperature is going to be with respect to expected atmospheric conditions. Research has shown that pavement temperatures can be forecast within 1°C (2°F) 90 percent of the time (2) and that site-specific forecasts are better than 80 percent accurate.

Such forecasts, in conjunction with the sensors that provide validation information related to the forecasts and detect road and weather conditions, allow managers to make other important decisions:

- Appropriate deicing chemical mixes can be selected. In the past, managers relied on air temperature to make mix decisions. Deicing is related to pavement temperature, and forecasts of pavement temperature let managers select the proper mixes ahead of time.
- Proper chemical application rates can also be selected ahead of time on the basis of forecasts of pavement temperature; they can also be adjusted on the basis of current sensor readings.
- If chemical treatment is part of snow removal plans, the decision to make an application can be based on the forecast of pavement temperature.
- Sensors and forecasts also help managers make the most cost-effective decision: to do nothing. Except for perhaps continual overhead costs, doing nothing costs nothing. If a forecast says pavement temperatures will be high enough that a road surface will not freeze, no maintenance action is required.
- Forecasts for the onset of winter weather and road conditions help managers mobilize forces to be ready to go when needed. Frequently, when in a reactive mode, managers find their forces behind the curve when applying chemicals or plowing snow. This can require more materials and time to achieve the desired road conditions.
- Similarly, knowing when a storm or conditions will abate helps managers stop snow and ice control activities when appropriate rather than, for example, waiting for the end of a shift.

Interagency Cooperation

Buying RWIS technologies can be expensive for highway agencies. Even though the responsibility for snow and ice control often ends at a political boundary, weather and road conditions do not. One measure that minimizes cost and maximizes information is for agencies to work together to implement RWISs.

- Within a highway agency, sharing data between maintenance districts or areas can reduce RWIS implementation costs. Where one district may require four or five RPU stations, and a neighboring area the same number, together the two districts may need sensors at only six or seven locations. Sharing information may also make forecasts less expensive, especially if the areas are similar climatologically.
- Interstate cooperation can help reduce costs. If sensor data from a maintenance office in one state can be used by a neighboring state, perhaps they can share the costs of the RWIS. Examples include Missouri using data from Kansas, or Wisconsin using data from Minnesota.
- Some of the most cost-effective cooperative efforts involve interagency cooperation. This can be accomplished when municipal, county, and state highway agencies get together to define their needs, find locations for sensors that can satisfy requirements for each or more than one agency, and share in the costs, perhaps on a pro rata basis. One example is in the Spokane, Washington, area where an airport authority, the state department of transportation, the city street department, and a solid waste utility with special weather information needs share information from RPU stations and use a common CPU for data access. They share the costs of the sensors and compute system maintenance costs on a pro rata basis.

Problems Noted

Cost savings, improved maintenance, and reduced decision errors are all positive results possible from using RWISs for snow and ice control. However, the research team identified some problems with implementing the technologies and with the technologies themselves. These implementation problems are referred to as "barriers": they can be philosophical, psychological, or institutional. Some of the barriers identified include

- Lack of buy-in at the maintenance operations level because of perceptions that the technology is directed from the top down. Many of the successful implementations have occurred when a maintenance foreman or supervisor has decided to go to management with a request for RWISs, rather than the other way around.
- No ownership at the operations level. This results when the person who initiates the implementation leaves the job and his or her replacement does not share the same philosophy or vision.
- Perception that the RWIS is a technological toy and certainly cannot help the maintenance forces perform their snow and ice control mission. Many of the decision makers have been working at snow and ice control for decades, and they believe that they know how to do it right.
- Reluctance to buy into a process at the operator level. This can result from operators perceiving a threat to their pocketbook. Many of the operators look forward to overtime paychecks from the winter activities. RWISs provide an opportunity to reduce overtime pay through more effective decision making.

Accuracy of data from the instruments can also be a problem. Pavement sensors can report temperatures not representative of the pavement temperature under sunlit conditions. Sensors, in general, can report erroneous readings when they are not calibrated routinely.

Another problem surfaces when sensors do not provide data that are representative of an area, which is the result of poor site selection or sensor location. Poor siting can result from decisions to locate RPU stations close to power or communications and consequently neglect sound meteorological and pavement siting practices. It is also possible that sites are selected solely because the operators perceive that a site is needed rather than consider overall RWIS data needs.

Communications can also be a problem. Frequently telephone lines are unreliable, and costs can be high if long-distance phone service is required to obtain data. RWISs from different vendors cannot exchange data because of incompatible communications protocols and data formats. The inability to exchange data can inhibit interagency cooperation.

Contracting procedures for RWIS technologies sometimes lead to undesirable effects. Forecasting services should be treated and acquired as professional services in a process that considers technical meteorological qualifications, not just cost. In addition, no hardware performance standards exist, and highway agencies tend to specify vendor-specific systems.

RECOMMENDATIONS

After the completion of the field trial and cost analysis and the evaluation of the information at hand, the following are the most important recommendations:

- On the basis of the cost analysis and the evaluation of the use of RWISs, all agencies that conduct snow and ice control maintenance should consider acquiring RWIS technologies.
- Training programs should be developed to help highway agencies implement RWISs. A properly designed training program can help personnel overcome the barriers to RWIS use. It is also often required to help managers integrate RWIS data into the decision process for snow and ice control.
- Agencies with RWISs in place should institute, at a minimum, an annual preventive maintenance program that includes semiannual calibrations of pavement and atmospheric sensors.
- Agencies contracting for RWISs should use a two-step acquisition process similar to contracting for other professional services when acquiring forecasting services. Performance specifications should be considered for adoption and used for buying RWIS hardware.
- Standard RWIS communication protocols should be adopted for CPU-to-CPU connectivity between RWISs. A standard data format should also be adopted in order to exchange RWIS data.
- Additional research will be required to

  –Determine the avenues for which interfacing or integrating RWIS information would be desirable (and, if possible, what it would take) as measured by criteria to be established. Possible interfaces include intelligent vehicle-highway systems.

  –Determine the utility of expanding RWISs to include new technologies such as present-weather sensors, radiometers, and visibility and air quality sensors to increase the cost-effectiveness of RWIS installations with more-detailed year-round support.

  –Establish motorist needs for RWIS information through studying human factors and behavioral science in order to provide information to effect behavioral change in drivers.

  –Develop standard calibration techniques for agencies to use for periodic pavement sensor calibration.

  –Determine the ability of data from on-board vehicle sensors to include infrared radiometers for pavement temperature, thermometers, and hygrometers, to enhance RWIS real-time information, to assist in developing historical data bases, and to provide thermal profiles of pavement temperature.

  –Evaluate the use of thermographic profiles in pavement temperature forecasting and the utility of using thermography for snow and ice control resource allocation staging or phasing by conducting road thermal analysis in at least three different climates.

  –Determine the utility of integrating RWIS (or other) in situ measurements into small-area, detailed forecasting models, perhaps as developed or in development through the Office of Atmospheric Research/Forecasting Support Laboratory of the National Oceanic and Atmospheric Administration, in order to improve decision support for transportation systems.

  –Evaluate the benefits to the meteorological community and to transportation for archiving RWIS data for climatological purposes, either with state climatologists or the National Climatic Data Center.

  –Determine the optimum role of the federal government in supporting surface transportation meteorological needs.

CONCLUSION

The SHRP H207 research has shown that RWIS can be a useful tool to improve the maintenance and reduce the costs of snow and ice control. Implementing the technologies requires that agencies develop a sound acquisition process and training programs to ensure the effective use of the data. Ongoing success will depend on how well the information is integrated into an agency's snow and ice control decision processes.

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