Weather Forecasting Strategies for Highway Snow and Ice Control Maintenance Operations

WA-RD 174.1

Final Report
January 1989

Washington State Department of Transportation
Planning, Research and Public Transportation Division

in cooperation with the
United States Department of Transportation
Federal Highway Administration

WASHINGTON STATE DEPARTMENT OF TRANSPORTATION

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO	2. GOVERNMENT ACCESSION NO	3. RECIPIENT'S CATALOG NO

4. TITLE AND SUBTITLE	5. REPORT DATE
Weather Forecasting Strategies for Highway Snow-and-Ice Control	January, 1989
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO
S. Edward Boselly III	MMG-B-02
9. PERFORMING ORGANIZATION NAME AND ADDRESS The Matrix Management Group 811 First Avenue Suite 466 Seattle, WA 98104	10. WORK UNIT NO
	11. CONTRACT OR GRANT NO Y-3993
12. SPONSORING AGENCY NAME AND ADDRESS Washington State Department of Transportation Transportation Building Olympia, Washington 98104	13. TYPE OF REPORT AN PERIOD COVERED Final Report, 1/88-1/89
	14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

This report describes a survey of weather impacts on current Washington State Department of Transportation (DOT) snow-and-ice control maintenance operations and how weather information is currently used within the DOT. The report further describes the capabilities of the meteorological community to provide meteorological and pavement condition data and the forecasting of future conditions. Finally, the report describes pilot programs which are recommended to investigate the ability of the Washington State DOT to reduce costs and improve resource allocation through the use of weather information in the snow-and-ice control decision process.

17. KEY WORDS	18. DISTRIBUTION STATEMENT
Highway maintenance, weather impacts, meteorology, snow-and-ice control	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22616

19. SECURITY CLASSIF. (of this report)	20. SECURITY CLASSIF. (of this page)	21. NO. OF PAGES	22. PRICE
None	None	26	

DOT FORM 310-022 (11/86) -1216-

WEATHER FORECASTING STRATEGIES FOR HIGHWAY SNOW-AND-ICE CONTROL MAINTENANCE OPERATIONS

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Final Report

Research Project Y-3933

Prepared for

Washington State Department of Transportation
and in cooperation with
U.S. Department of Transportation
Federal Highway Administration

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WEATHER FORECASTING STRATEGIES FOR HIGHWAY SNOW-AND-ICE CONTROL MAINTENANCE OPERATIONS

SUMMARY

This study found that contrary to the belief that little research has been conducted in the use of weather information in snow-and-ice control operations, considerable research has been conducted in Europe. This research has included investigating the use of pavement and meteorological sensors; the availability of predictive models for specifying future conditions of both pavement and the atmosphere; and techniques for analyzing thermal characteristics of road segments and structures in order to determine optimum sensor locations and density.

A survey of current practices within the Washington State Department of Transportation (DOT) maintenance operations showed there is no formal program to use weather information in the resource allocation decision process. The informal use of weather information usually includes either time-consuming and expensive procedures for gathering weather data or contracting for weather forecast support from private meteorological firms. The latter is usually on an Area by Area basis within a Division; the former is on a technician by technician basis, i.e., usually the personal preference of a maintenance technician.

Following the analysis of Washington State DOT snow-and-ice control maintenance procedures, it was evident that weather information could and should be incorporated into supervisory decisions in order to better answer questions such as,

"Will road surface temperatures be below freezing during the next 12-18 hours, and if so, by how much?"
"Will the roads be dry, wet, or icy?"
"Is snow forecast to accumulate, and if so, how much at what rate?"

Because of the varied climatic regions within Washington State, and the different possible response procedures to deal with snow and ice on highways, no single process can be described which would incorporate weather information into

the maintenance decision process. However, certain generic types of weather information should be considered:

- o on-site pavement and meteorological conditions; and
- o forecasts for pavement and meteorological conditions.

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

1. Too infrequently Washington State Department of Transportation maintenance decisions for snow-and-ice control are based on operational intelligence provided by forecasts of either pavement or weather conditions.

2. The use of forecast pavement and weather conditions in highway maintenance operations has the potential to reduce labor, equipment and material costs for snow-and-ice control and in turn make the equipment and labor resources available for other highway maintenance activities.

RECOMMENDATIONS

1. Washington State DOT conduct at least two Pilot Programs, one in Western Washington and one in Eastern Washington, to investigate the ability of weather data and forecasts to reduce snow-and-ice control maintenance costs.

2. Washington State DOT conduct a pilot study to investigate the benefit of contracting for consulting services on the hiring of a meteorologist to perform staff duties within the DOT for coordinating weather-related activities.

3. Washington State DOT consider conducting further research to investigate the transfer of emerging meteorological technology, including remote sensing and expert systems, to enhance the decision-making process for snow-and-ice control operations.

INTRODUCTION

RESEARCH OBJECTIVES

The objectives of this study were 1) to investigate the ability to reduce the costs of highway snow-and-ice control maintenance operations through the use of weather forecasts and weather information, and if the investigation indicates a relatively high probability that costs can be reduced, 2) to design pilot projects which could be used to investigate methods to reduce those costs. In order to achieve the objectives, the following tasks were accomplished:

1. A literature search was conducted and the findings of that search were summarized;

2. Washington State DOT highway maintenance personnel were interviewed to determine

    a. the weather impacts on highway maintenance operations, particularly for snow-and-ice control,

    b. current snow-and-ice control responses and typical maintenance activities under various weather conditions,

    c. the highway maintenance decision processes employed within the Washington State DOT in snow-and-ice control situations, and

    d. the extent of weather information being used by highway maintenance personnel in their decision processes;

3. In order to ascertain the current technology available to the meteorological community to provide information required for support to highway operations,

    a. meteorological firms were solicited to provide instrumentation information; and

b. a limited number of interviews with meteorological-services providers were conducted to determine the ability of the meteorological community to provide the type of information necessary for highway maintenance personnel to make their decisions.

4. Based on the literature search, interviews, and the analysis of the state-of-the-art in meteorological support, pilot programs were designed which could be conducted to investigate the ability to reduce costs in snow-and-ice control operations through the use of weather information.

THE PROBLEM

The ability of highway maintenance organizations to continue to maintain roadways and structures at the current level may in some respects become a function of their ability to minimize costs in the face of decreasing Federal assistance and increasing age of the infrastructure. To compound the problem, there are more and more demands on current budgets as requirements for funding increase frequently faster than the revenues which are available.

In many areas of the United States, as well as North America in general, and Europe, maintenance responses to snow or ice weather conditions are the single most costly maintenance activities. It has been estimated that from $800 million to $2 billion are spent annually in North America in the application of salt and other chemicals; another $1 billion are spent in snow removal. In sum, nearly $3 billion are spent annually in North America for snow-and-ice control(1) These are only direct costs.

Indirect costs also accrue from snow-and-ice control maintenance activities. Salt applied to roadways and structures causes severe corrosion damage to concrete and rebar as well as any other metal supporting structures. Chemical corrosion also affects vehicles, and the cost nationwide of preventing or repairing this corrosion is very large. Not even estimated are the environmental damages to streams and lakes, as well as roadside ecosystems, from salt. In addition, abrasives applied must be swept from roads; snow plow blades damage markers; and equipment rental funds (vehicle maintenance, etc) must be

escalated to provide for winter maintenance of maintenance vehicles and equipment.

In Washington State, the Department of Transportation (DOT) budgets over $30 million per biennium for direct maintenance costs for snow-and-ice control. This budget is for labor, equipment and material usage which will be charged for direct snow-and-ice control maintenance activities. About 80% of the budget is allocated equally to labor and equipment; the remaining 20% is approximately two-thirds to materials and one-third to contracts. The contracts are primarily for opening mountain passes closed due to snow for the winter.

Reducing costs could be done by decreasing labor, equipment or material costs, or any combination of these three. For instance, cutting back on the number of labor hours expended in snow-and-ice control maintenance activities generally includes associated reduced vehicle and equipment hours: plowing or blading crew requires the use of plows or graders; and sanding requires the use of sanders. The latter example also includes costs of materials.

If maintenance personnel could know exactly what the weather and pavement conditions would be, then assuming the maintenance practices and people are efficient, the supervisors could assign tasks and the people to perform them precisely when needed ... and then release them from duty when the work is complete. The ability to assign resources in this manner would require a perfect weather and pavement condition forecasting capability. Table 1, (below) shows how maintenance management people could use such a forecasting capability.

The benefits suggested in Table 1 usually are construed to be a result of bad-weather forecasts. However, knowing that the weather will be good allows for increased flexibility in accomplishing scheduled and unscheduled highway maintenance activities. This investigation will focus on determining the present meteorological capability to provide accurate enough information for a time period which would allow maintenance personnel to make better resource allocation decisions and thereby reduce maintenance costs.

Table 1

Perfect Forecast Capability Period		Benefits
More than one year	-	Prepare accurate biennial budget
One year	-	Adjust annual budget to reflect proportions of maintenance needs
	-	Stockpile materials
Seasonal	-	Hire temporary/seasonal employees when needed and plan their release
Monthly	-	When to start multi-shifts
	-	When to start, release seasonal/temporary employees
	-	How to schedule holiday season work shifts
Weekly	-	Plan maintenance activities
Daily	-	Start and Stop extra shifts, call backs, call outs
	-	Schedule maintenance activities

REVIEW OF CURRENT PRACTICE

INTRODUCTION

This section summarizes the results of the literature search initiated at the outset of this project, the interviews conducted with Washington State DOT highway maintenance personnel, and information gathered from the meteorology community following the literature search and interviews. An evaluation of the results is also presented.

The purpose of the literature search was to:

1. document the impact of weather on highway maintenance activities;

2. ascertain the body of knowledge relative to the use of weather information by highway maintenance organizations;

3. document the meteorological hardware and services in use (if any) in support of highway maintenance activities, especially for snow-and-ice control;

4. determine the order of magnitude of cost savings (if any) in highway maintenance activities through the use of weather information; and

5. provide a foundation for discussing the use of weather information with highway maintenance people and the meteorology community.

The purpose of the Washington State DOT interviews was to:

1. document the impact of weather on highway maintenance operations and to find critical thresholds for important weather parameters;

2. determine the typical Washington State DOT maintenance snow-and-ice control responses to weather and pavement conditions;

3. determine the limitation (if any) to flexible response in light of weather conditions;

4. ascertain the current level of use (if any) of meteorological information within the Washington State DOT;

5. determine the willingness to (continue to) use such information and any benefits to be (which have been) derived from its use; and

6. find locations which could serve as candidates for further research in the conduct of pilot programs.

The purpose of surveying the meteorological community was to:

1. estimate the state-of-the-art in measuring meteorological parameters considered critical to highway maintenance activities;

2. estimate the ability of the meteorological community to provide forecasts of critical parameter thresholds and over what time period; and

3. determine the costs of meteorological hardware and services.

In order to conduct the interviews, a standard interview guide was prepared. Requests for information on meteorological hardware were mailed to known purveyors of such hardware based on professional publication advertising and prior knowledge of the investigator. Descriptions of pertinent meteorological services available were provided through personal contact with providers of such services, and information obtained from professional literature and previous investigations.

RESULTS OF THE LITERATURE SEARCH

Literature searches were initiated in Washington, D.C., at the U.S. DOT Library and in Washington State at the University of Washington Library. At the outset of these searches, frequent reference was found on studies of snow-and-ice control practices and procedures, but little reference is made to actually using weather information to alter or improve these or to make better decisions, at least

in the United States. While conducting the literature search, it was discovered in the February, 1988 issue of the Bulletin of the American Meteorological Society that a publication entitled A Bibliography of Snow and Ice Hazards on Highways, published by the National Snow and Ice Data Center and the National Hazards Research and Application Information Center was available. Upon obtaining this document, it soon became apparent that the body of knowledge on the use of weather information resides mostly in Europe. For over a decade, research has been conducted on developing meteorological and pavement sensor systems and forecast models to be used to provide weather and condition information to highway maintenance decision-makers. Examples include:

1. The development of the National Ice Prediction System in the United Kingdom;

2. SWEROAD, a consortium of Swedish government-backed Swedish firms providing total highway maintenance needs, including road weather information systems;

3. The Organization for Economic Cooperation and Development (OECD), an international group which is conducting research into reducing the use of salt in snow-and-ice control;

4. The Standing European Road Weather Commission (SERWEC) which works to tie road weather information system development together between national efforts in Europe; and

5. The Transportation and Road Research Laboratory (TRRL) in the United Kingdom which conducts road weather information system basic and applied research.

In addition to what at one time might have been considered typical meteorological services, i.e., meteorological sensors and weather forecasts of events of interest, new capabilities have been developed and tested in Europe and are now in regular use. The technology is just beginning to be transferred to the United States.

For instance, at the University of Birmingham, in the United Kingdom, Dr. John E. Thornes developed a technique for conducting an analysis of the thermal characteristics of a road segment. The technique, called thermal mapping, involves the measurement of roadway temperature using an instrumented van with a downward looking radiometer and computer plotting measured temperature versus road position under varying atmospheric conditions. The thermal mapping technology purportedly can assist in the determination sensor numbers and their locations, serve as a basis for pavement temperature forecasting, and assist in the development of snow-and-ice control plans through pinpointing areas on road segments which would need attention first under various weather conditions.

In addition to thermal mapping, Dr. Thornes developed a pavement temperature forecasting model and pioneered an effort with The British Meteorological Office to provide forecasts of pavement conditions based on sensor input and expected weather conditions to highway maintenance agencies. Called the National Ice Prediction System in The United Kingdom, this effort should soon include all the counties in England. The thermal mapping and the forecast model technologies are both transferring to this continent via private meteorological firms.

The investigator also reviewed reports from the Wisconsin and New Jersey DOTs on their use of meteorological information. Both state reports suggested substantial savings were possible in snow-and-ice control maintenance operations. Additional articles reviewed showed St. Louis and Chicago and the State of Colorado were using similar sensing equipment and, too, expected substantial dollar savings. All agencies indicated savings in over-time costs and in the reduction of materials usage. (In contrast, however, during personal conversation, a representative from the Michigan DOT suggested that there were no perceived savings from <u>their</u> use of weather information; however, no formal evaluation had been conducted.)

RESULTS OF INTERVIEWS AND FOLLOW-UP REQUESTS

Interviews were conducted with highway maintenance personnel in Washington State DOT Headquarters and in the field. Field interviews included maintenance people in Districts 1, 2, 4 and 6. In addition to these interviews, the

personal contact included attending a Washington State DOT Snow-and-Ice-Control Steering Committee meeting. The Steering Committee is made up of representatives from DOT Headquarters and each DOT District; its membership is multi-disciplined in order to avoid parochialism and to benefit from the possible synergism of diversity.

Interviews were conducted in private, one-on-one sessions, as well as in open group question-and-answer sessions. Each type of session provided outstanding results, a tribute to the open-mindedness of the interviewees and their desire to do their job the best way possible.

IMPACTS

All interviewees agreed that weather impacts their operations, but generally to different degrees. Each Area of each Washington State DOT District has its unique weather conditions and circumstances. For snow-and-ice control operations, with the exception of the Cascade mountain passes, the following are the significant weather phenomena which affect highway maintenance operations:

1. the accumulation of sufficient quantities of snow to require removal;
2. the formation of frost causing slippery surfaces; and
3. the deposition of ice from freezing rain or the formation of ice.

Each of these phenomena occurs in varying degrees. The snow accumulation can be localized and of relatively short duration as well as wide spread and of such significant amount to require continuous removal efforts for round-the-clock shifts. The frost formation can also be localized in "frost hollows" and wide-spread such as rime ice deposition from winter fog in Eastern Washington.

LEVEL OF SERVICE

Of concern also is the level of service which is required for the particular maintenance response to the weather conditions. The Washington State DOT Maintenance Manual specifies the following priorities and levels of service (5)

1. Assigned to:
   - o The Interstate System.

- o All sections of highways having an average daily traffic (ADT) of 10,000 or more.

Service Level:

- o Appropriate snow control operations begin before 1 inch of snow has accumulated.
- o Appropriate ice control operations begin when ice conditions are evident.

2. Assigned to:
   - o All sections of highways having an ADT of less than 10,000 but more than 1,000.

   Service Level:
   - o Appropriate snow control operations begin before 2 inches of snow have accumulated and after priority one sections of highway have been considered.
   - o Appropriate ice control operations begin when ice conditions are evident and priority one sections have been considered.

3. Assigned to:
   - o All sections of highway having an ADT of less than 1,000.

   Service Level:
   - o Appropriate snow control operations begin before 3 inches of snow have accumulated and after priorities one and two sections of highway have been considered.

4. Assigned to:
   - o Selected mountain pass routes that are allowed to close during the winter.

   Service Level:
   - o Treated as priority three highways until such time as the District Administrator determines operations and/or travel are too hazardous.

More typical responses, however, vary as much within The Washington State DOT Districts as do the weather phenomena. Examples of the variation include the effort undertaken to continuously remove accumulated/ accumulating

snow over Snoqualmie Pass on I-90 to the decision to insure I-90 is passable to vehicles without traction devices in Lincoln County.

Not only do the types of responses vary. The shift schedules employed to combat winter weather vary within Districts. Most of District 5 highway maintenance people go to 24-hour operations with double shifts in November; Area 4 of District 5 runs double shifts but some 4-5 hours are not usually covered. In Area 4 of District 1, only the higher elevation regions East of Enumclaw get 24-hour winter coverage, with a midnight shift skeleton crew elsewhere.

Because of the varied weather, most Areas will, when conditions warrant, conduct Winter Safety Patrols. Maintenance personnel drive around their area of responsibility checking, for instance, known icing trouble spots, and strategically placed thermometers in order to stay ahead of or on top of the maintenance required. The costs charged to this activity run close to 15 percent of the snow-and-ice control maintenance budget. It appears the use of weather and pavement sensors could significantly reduce this cost alone.

LIMITATIONS TO RESPONSE

Throughout the Washington State DOT, certain conditions exist which limit the flexibility the maintenance management personnel have in responding to snow-and-ice control situations. One such limitation is imposed by labor agreement. Supervisors must provide at least seven-days notice to change the shift of a bargaining unit employee. Also, under Merit System rules, in Areas where multi-shift schedules are implemented for the winter-weather season, senior employees have first choice of the shifts they wish to work. The net result can be, and in some instances is, the least desirable shifts lack experienced people. Another limitation is the cost of overtime for callouts and callbacks.

As a matter of policy, the biennial maintenance budget for snow-and-ice control is based on an average of the last four years' expenditures, and then inflated or deflated at the same rate as the remainder of the budget. Each District and hence each Area is given a "bottom line" for snow-and-ice control each year. If expenditures exceed the "bottom line", then the Area or District uses funds budgeted for other maintenance activities to cover the deficit.

Therefore there is real incentive to reduce snow-and-ice control costs since other maintenance activities may suffer from reduced funds.

USE OF WEATHER INFORMATION

Nearly all Winter-time highway maintenance people in the Washington State DOT use one form or another of weather information. They use it because they recognize the need to know what the current conditions are and what the conditions are expected to be. However, the gathering and processing of the information is, for the most part, primitive.

The Washington State DOT's weather data collection program is, with few exceptions, primarily a time-consuming, manual reading of thermometers strategically placed on sign posts or structures in order to determine ambient conditions. As the air temperature approaches or goes below freezing, snow-and-ice control maintenance actions might take place. The exceptions to the manual data collection include indoor-outdoor thermometers with digital readouts installed in some DOT maintenance vehicles, and pavement sensors and some meteorological instrumentation in and around Snoqualmie Pass. These instruments provide data for both highway maintenance operations and avalanche condition forecasting.

Some Areas also have contracted with a private meteorology firm to obtain weather forecasts of importance to highway maintenance activities, in particular icing conditions and snowfall accumulation. There are mixed feelings within the maintenance community as to the utility of the forecast service. These opinions range from "very helpful" to "not sure", but no extremely negative opinions were received. It is the investigator's belief that three reasons cause the mixed feelings.

First, the weather forecasts are for atmospheric conditions usually and not pavement conditions. The maintenance people have not worked hand-in-glove with the meteorologists to establish the thresholds of importance for critical parameters and to tailor the forecasts to specific needs. Second, because the forecasts are for atmospheric conditions, the maintenance people try to translate the forecasts into pavement condition forecasts, with only limited success. And

finally, no mechanisms, such as snow-and-ice control plans specify how weather information should be used in the decision processes.

WILLINGNESS TO USE WEATHER INFORMATION

In nearly every instance, maintenance supervisors and managers recognized that weather information could help them manage their operations more effectively. This recognition is also accompanied by a strong desire to implement emerging technology and to participate in pilot programs designed to investigate further the use of weather information.

The willingness to participate is also further bolstered by concern over budget constraints and belief that some current practices may need to be changed. Most managers interviewed feel especially strongly that with proper weather information, Winter road patrolling expenditures could be reduced significantly.

CANDIDATE LOCATIONS

Because of the variation of climate within Washington State, opportunities exist in every Area of the six Districts of the Washington State DOT to implement road weather information systems. Each maintenance person interviewed identified specific problem areas, road segments or structures, the maintenance of which could be improved for snow-and-ice control. Due to limited research funds, only a limited number of locations can be selected.

Two specific areas, because of significant weather problems, interest among the highway maintenance community, and opportunities for interjurisdictional cooperation, appear extremely favorable for further research: The City and County of Spokane urban area and the South Snohomish County - City of Everett area. The actual pilot programs, if implemented, would be specified after discussions with Washington State DOT Headquarters and appropriate District personnel, in conjunction with other jurisdictions.

RESULTS OF SURVEYS OF THE METEOROLOGY COMMUNITY

Weather information of use to highway maintenance personnel can come from two sources: sensors that provide data on current conditions, and forecasts

from meteorologists for expected conditions. In order to specify how these sources could be used, it was first necessary to determine the availability and applicability of data sources and forecast services. The following sections describe the information gleaned about meteorological hardware and services.

METEOROLOGICAL HARDWARE

Meteorological sensors have been used for decades, primarily in support of aviation. In the 1960's, attempts were made to use sensors placed in pavement in order to obtain pavement temperature and thereby warn motorists of icing conditions. Unfortunately, the sensors were inaccurate and unreliable. In the last ten years, great advances in sensor technology have overcome the previous problems.

Reliable and accurate sensors can now be placed in pavement to obtain pavement temperature, the pavement condition (wet or dry, ice), and a measure of the amount of chemicals on the road which would prevent freezing. Hundreds of pavement sensors are in place in roadways in Europe; over 100 are in place in this country, the majority being at airports. However, the number of roadway sensors is increasing.

Wherever pavement sensors are placed, meteorological sensors are usually collocated. The primary reason is that the meteorological data are required for weather forecast models. Pavement temperature and ambient temperature are not usually the same, but both are needed to predict as accurately as possible the pavement temperature which is what is important. Freezing or thawing on road surfaces is a function of the pavement temperature. However, temperature is not the only meteorological parameter of interest.

The suite of meteorological hardware usually found at roadside also include devices to measure wind speed and direction, dew point temperature or relative humidity, atmospheric pressure, and precipitation. Recent technology advances in precipitation measuring devices include optical devices which can indicate even light snow has begun to fall. In some locations, optical devices are also used to measure the visibility. The formation of fog with pavement temperatures at or below 32°F can produce severe road icing conditions. Some forecast models also require knowledge of subsurface temperatures in order to

determine heat transport. Consequently, some sensor suites now include a subsurface temperature sensor, usually placed about 16 inches below the surface.

The key to implementing a successful data gathering process is how the data are processed and transmitted from the on-site location to the "user". That user may be a maintenance supervisor or a meteorologist. But both need the data in a useable form in a timely manner. The survey of the hardware capabilities also revealed many possible methods for data collection. Two standard methods use telephone or radio transmission of data, either directly to maintenance personnel or to a communications network linking meteorologists and maintenance agencies. Ideally, however, a Statewide communications network which could be used to transmit data and forecasts would provide for the best use of available information. This would allow interchange or sharing of information between DOT Districts and Areas and would significantly increase the availability of data to forecasters, as well.

METEOROLOGICAL SERVICES

The spectrum of available weather services, specifically forecasts of weather, is very broad. It includes, at one end, public forecasts which are usually of a general nature covering a geographical area. At the other end of the spectrum are forecasts of specific parameters provided to clients with a specific need. In general, the public forecasts are provided by the National Weather Service and media; the "tailored" forecasts, except under special circumstances, are provided by value-added, private meteorology firms to paying customers.

Ideally if decision makers are to use weather information in the decision process, then the information should be as explicit as possible and focussed on critical thresholds for key parameters. For highway maintenance personnel concerned with snow-and-ice control, the key parameters include pavement temperature, precipitation type, amount, and the time of occurrence and duration of precipitation or icing conditions. While most private meteorology firms that provide forecasting services will issue forecasts of precipitation events and atmospheric conditions, their ability to specify pavement conditions is limited. Unfortunately, that is what the snow-and-ice control maintenance people need, for both planning purposes and for decisions to take appropriate action.

As indicated in the literature search, research in Europe has led to the development of pavement condition forecasting models. This technology is slowly transferring to this continent. One private meteorological firm in the United States is currently providing such forecasts and is marketing total road weather information systems which include sensor packages. (This investigation did reveal the possibility of other firms developing similar capabilities. The need and importance of the capabilities are being recognized.)

Emerging technologies in atmospheric measurements and information processing also could have significant impact on the ability to provide weather information to highway maintenance organizations. The computational power of the National Doppler weather radar program, the Next Generation Weather Radar (NEXRAD), will provide unprecedented radar products, including precipitation amounts. Low-power Doppler weather radars are already being installed in some areas because of their ability to detect light precipitation, heretofore not possible with "storm" weather radars.

Information processing with micro-computers and mini-computers is providing meteorologists with new capabilities in data analysis through the use of interactive graphics. These Automated Weather Information Systems (AWISs) are allowing forecasters to look at and correlate more data than though humanly possible. The ability to ingest data into such AWISS from road weather information systems will significantly increase the ability to provide forecasts for highway maintenance operations.

Meteorological satellite imagery capability could improve to the extent that "thermal mapping" may become a reality from space. High resolution infrared imagery could provide the "cloudless sky" thermal patterns; high resolution microwave imagery could provide the "cloud-covered" thermal patterns. These data combined could provide all the information currently obtained while on the road.

Under development in Boulder, Colorado, is the Prototype Regional Observing and Forecasting System (PROFS) which is at the cutting edge of providing meteorologists with workstations which can ingest, process and display data from dense networks of highly sophisticated sensors, NEXRAD imagery, and meteorological satellite imagery. The processing includes the development of

forecasting models for local area phenomena and on short time scales. The very fact that all this promising technology is emerging should not go unnoticed at a time of increasing awareness of the possibility of reducing costs in highway maintenance snow-and-ice control operations through the use of weather information.

PILOT PROGRAMS

The results of the previous section showed that the interviews with highway maintenance personnel responsible for snow-and-ice control operations revealed a need for accurate and timely weather information in order to make better decisions in resource allocation and to reduce costs. The literature search and information gleaned from the meteorology community indicate technology is emerging in this Country to provide the kinds of information needed.

It follows that further research should be undertaken to test the new technology within the framework of Washington State DOT maintenance operations. Carefully designed pilot programs should show the cost effectiveness of using weather information on a variety of scales, i.e., from using remote sensor inputs (instead of winter road patrols, perhaps) to a full-up road weather information system with road segments thermally mapped, sensors in place, and pavement condition and weather forecasts provided.

Because of the varied nature of Washington State's climate and the snow-and-ice control procedures, a minimum of two pilot programs should be conducted: one in Eastern Washington and one in Western Washington. In concept, each pilot program would be of similar design and would be used to analyze reducing Winter road patrol costs and to respond to storm situations.

1. Thermal mapping of a Washington State DOT maintenance Area's roads would be conducted, perhaps 400 center-line miles. The thermal mapping would be used to select optimum sensor locations.

2. Two to four suites of sensors would be placed based on a., above.

3. A computer-based display would be installed at Area Headquarters for monitoring of sensors, receipt of forecasts of pavement conditions and weather, and for serving as a communications hub for the system.

4. Remote terminals, either computer-based or dumb, would reside at remote maintenance sheds where many of the operational decisions are made. Supervisors or head Technicians could query sensors, monitor sensor output, or monitor forecasts in order to make decisions.

Appropriate evaluation instruments such as logs, would be used to record decisions made and actions taken as a result of the weather information. In addition, an attempt would be made to ascertain what action would have been taken had there been no road weather information system.

At the end of the winter, costs would be summarized based on the normal cost accounting procedures. The Winter would be categorized quantitatively in terms of means of temperatures and precipitation, heating degree days, days with precipitation, etc., to compare with the previous four years (budget inputs) and the average costs for those four years. Typical cost savings estimates due to a road weather information system would be documented and projections of system amortization developed.

It is recommended that these pilot programs be initiated quickly to insure that installation can be completed prior to the 1988-1989 Winter. In addition, it is also recommended that further investigations be carried out on the effective use of weather information in three additional aspects. First, an analysis of the ability to use weather information to adjust shift schedules should be conducted, both to determine the most cost-effective response to weather situations given current Merit Service Rules and negotiated labor agreements. This analysis would be based on a simulation of alternative responses and scheduling based on weather forecasts. It is expected the analysis would show similar results to other studies which indicate a labor costs savings of one-hour (times the number of people responding) per snowstorm, up to Statewide.

Second, relatively low-cost, low power weather radars have been developed which can detect light precipitation of the kind usually occurring in the Pacific Northwest. An analysis should be made of the utility of using such data to further enhance the knowledge of snow-and-ice control decision makers. The analysis should also include whether the interpretation of such data is possible by maintenance decision makers or whether the interpretation is best left to meteorologists providing the weather service; in either case, its benefit has been demonstrated in other agency tests. Pennsylvania DOT is regularly using radar for both winter and summer operations. And, in the Seattle area, the cost would be very slight since Seattle-Tacoma International Airport is installing a system and only a remote readout would be required.

Finally, it is evident that one of the keys to success in using weather information is to have a weather information is to have a weather-service provided who understands the customer's needs and can translate those operational needs into meteorological support requirements. Where that support should reside, however, is not clear. The range of options included:

- o total support from outside, private contractors or governmental agencies;
- o use of a consulting meteorologist to help tailor requirements and act as a facilitator;
- o in-house staff meteorologist...a captive consultant; and
- o in-house meteorological services capability.

An analysis should be conducted to determine the most cost-effective means of providing both the staff and operational weather support functions.

The initiation of all or part of these pilot programs will help to document in Washington State DOT highway maintenance operations the cost savings possible Statewide. Continuing with the next phase of this research is an important next step.

ACKNOWLEDGEMENTS

The author wishes to express sincere appreciation to the Washington State Department of Transportation people whose support was absolutely essential in initiating this research: Mr. Donald Ernst, State Maintenance Engineer (retired); Mr. Dennis Ingham, former Highway Maintenance Engineer, now State Maintenance Engineer; and Mr. Donald Tranum, District 6 Administrator. Special thanks also must go to each field maintenance person interviewed. Their cooperation and willingness to help assured the success of this investigation.

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