APPENDIX H
Weather & Environmental Detection

SUMMARY

TEST AND EVALUATION PROJECT NO. 11

ICE DETECTION AND HIGHWAY WEATHER INFORMATION SYSTEMS

I. BACKGROUND

Since 1962, a number of State highway agencies have installed or investigated the performance of ice detection systems and various types of weather forecasting services. After three decades of testing and development, today's ice detection equipment can provide increased accuracy and reliability. The emphasis of past evaluations however, has been on system operations and performance. The usefulness, effect on maintaining a safe highway, and cost-saving aspects of these systems had not been thoroughly studied and as a result, had not been totally integrated into the decision making process. To encourage and assist State highway agencies in evaluating the usefulness of the data from their existing systems, the Federal Highway Administration (FHWA) initiated Test and Evaluation Project No. 11, Ice Detection and Highway Weather Information Systems, in 1988. This project was originally identified as Special Experimental Project No. 13, but was changed in 1990. The objective was to clearly document the usefulness of ice detection and highway weather information systems in maintaining highway safety during winter weather and reducing salt or winter chemical and personnel needs for snow and ice control. A total of eight cooperating agencies agreed to evaluate their use of these systems over the winters of 1989 and 1990.

A. ICE DETECTION AND HIGHWAY WEATHER INFORMATION SYSTEM USED

All participants used the SCAN system and SCAN-CAST service from Surface Systems, Incorporated (SSI). This commonality is not surprising given SSI's dominance in the highway weather information field within the United States. The SCAN hardware basically consists of:

A. Surface sensors which monitor pavement temperature and surface conditions including presence of ice, frost, water, snow and chemical concentration.

B. Atmospheric sensors which monitor air temperature, dew point, relative humidity, precipitation, wind direction, and wind speed.

C. Remote processing units (RPU) which collect and transmit surface and atmospheric data to a central processing unit.

D. A central processing unit (CPU) which processes all data for graphic presentation and sends data to remote terminals.

The SCAN-CAST service forecasts pavement temperatures and highway conditions, and provides snow, ice and severe storm warnings.

For the remainder of this report, this package of hardware and prediction service will be referred to simply as the system. similar equipment and forecast services are also available from other vendors including the Climatronics corporation and Vaisala, Incorporated. The addresses and telephone numbers of these vendors are included in the Appendix.

B. COOPERATING AGENCIES

Colorado Department of Transportation

District of Columbia Department of Public Works

Idaho Transportation Department

Kansas Department of Transportation

Michigan Department of Transportation

National Park Service, National capital Region

New Jersey Department of Transportation

Virginia Department of Transportation

C. METHODOLOGY

To enable a comparative analysis of the benefits derived from such systems, the information collected by the various participating agencies had to have a certain degree of uniformity. For this reason, three forms were developed for the agencies to use in collecting information. Copies of these forms are included in the Appendix. Details of winter maintenance events, the costs associated with related maintenance activities, and specific site information were recorded on the forms. This information, along with accident records and reports on motorist delays, were to be used to determine system effectiveness and resultant cost savings. This necessarily involved value judgements based on what action(s) would have been taken without the additional weather, pavement condition, and pavement surface temperature predictive information. The amount of event details and cost information ultimately documented varied among the participants. A discussion of their experiences follows.

D. PARTICIPANT EXPERIENCES

COLORADO DEPARTMENT OF TRANSPORTATION (CDOT)

CDOT's evaluation of its system centered around its Denver-metro area operations. As of 1991, this area was covered by one CPU and eight RPU'S. The system became operational in early 1987 with just two RPU'S. The winter of 1987 was basically spent becoming familiar with the system. Since then, the system "has been used as a standard tool for winter maintenance." In performing the evaluation, difficulties were encountered in trying to determine what decisions might have been made had the system information not been available and in establishing cost differences due to the use of the system. The difficulties were mainly due to the large effort required to track the decision-making process during winter storms and the many variables which influence the costs of snow and ice control. Before/after type comparisons were found to be difficult due to variations in the severity of the winters.

System information is used in the decision process on whether to mobilize shift personnel for snow and ice control and when to use contractors to supplement State forces. These decisions are made by the Section Maintenance Superintendent who is responsible for the Denver-metro area. There are six maintenance foremen, each responsible for a portion of the metro area, who report to the superintendent. Feedback on use of the system was obtained from five of the foremen through interviews. Of the four foremen who had portable computers which gave them access to system information, three used them mostly at the beginning of storms to help formulate activity plans. The other foreman accesses the system mostly after storms to see how well his crews had performed. The problem of not being able to find a free line to access the system just before or during a storm was cited by two of the foremen. The foreman with no access expressed the opinion that "since maintenance forces will be out anyway, the system does not give any new information."

Attempts were made to determine the effects of the system on accident rates by comparing before/after accident data at one site. Unfortunately, nothing tangible was determined due to changes in the accident reporting threshold at about the same time the system became operational. Actual salt/sand usage in the metro area during the winter of 1989 was compared to predicted use based on a multiple regression technique and showed a decrease which could possibly be attributed to use of the system. The reduction in material and labor costs was estimated at $44,000, which is equivalent to 10% of the cost of the installed system. Although no solid figures were available to support their claims, the users indicated that personnel overtime reductions during storms have been realized because of the system. The reductions resulted from pavement temperature information which enabled delayed mobilization and/or earlier termination of operations.

The overall conclusion by CDOT was that both material usage and overtime costs appear to have been reduced by the use of the system. It was found that a learning period is required for the users to develop a feel for and trust in the information before the system is used effectively. Realization of full benefits from the system will therefore be gradual. The need to encourage acceptance of the system, and for training in both how to use the system and strategies for improving efficiencies is evident. There appears to be general satisfaction with the system and expansion seems likely.

DISTRICT OF COLUMBIA DEPARTMENT OF PUBLIC WORKS (DCDPW)

The DCDPW has one CPU and three RPU's within its jurisdiction. The system was installed during the winter of 1988. The system was initially set up with cooperation from the Virginia Department of Transportation and the National Park Service, with each contributing an RPU (Virginia has since expanded its system and obtained its own CPU). The winter of 1989 was spent familiarizing users with the system, verifying accuracy, and developing guidelines for system usage. Thus, operation experiences were only compiled for the winter of 1990 which, unfortunately, was an unusually mild one. For this project, only one location (Michigan Avenue Bridge) was evaluated. Monitoring of the system occurs only during normal business hours except under storm conditions. When winter storms are imminent, the decision makers maintain constant access to the system via portable computers.

During the 1990 winter, information provided by the system was used in the decision making process for eleven events. On five occasions, the decision not to spread abrasives was made based on pavement temperature information provided by the system. This saved an estimated amount in excess of $11,000. On three occasions, the decision not to activate maintenance trucks was made based on system information. No information was available on savings in personnel hours. Indications were that the system also provided information which enabled more timely treatment of icing conditions. However, it appears that the users still lack complete faith in the accuracy of the system. On seven occasions, it was indicated that surve4illance personnel ‘were sent to verify sensor information.

The DCDPW concluded that the system will be a valuable tool in its snow removal program. Although the users have yet to develop complete trust in the system, reductions in personnel, equipment and material costs have still been realized. The potential for more significant savings in the future is anticipated. Safety may also be enhanced using information provided by the system to reduce the potential for black and glaze ice conditions (where a thin layer of ice forms on top of the pavement from freezing rain or moisture in the air).

IDAHO TRANSPORTATION DEPARTMENT (ITD)

ITD’s system was installed in 1986 and consists of four RPU’s and one CPU. All sensors are located on a sixteen mile stretch of Interstate at the south edge of Boise. Use of the system during the winter of 1989 was evaluated. There was no indication of why the winter of 1990 was not also evaluated. The accuracy of air temperature readings and weather forecasts were reported to be very good. During the study period, information from the system was not used in the decision-making process. There was an unwillingness by the decision-makers to rely solely on information from the system as a basis for crew response due to the importance of the study section. Also, equipment malfunctions experienced during two consecutive winters reportedly affected user confidence in the system. In any case, State policy regarding use of the system states that “this information is not to be used as the sole factor in dispatching by supervisors.” No reductions in personnel hours could be saved “since the crews must be out to report on the other routes anyway,” and since crews must be on the road by 4:00 AM, two to three hours before the first system report is printed out each day. Although the two foremen with maintenance responsibility for the study section had access to the system through computers in their homes, it appeared that the system is only monitored during regular office hours. The geographical location of the existing system did not appear ideal. It was indicated that the majority of major storm fronts moved in from the west while the RPU’s are concentrated in the east.

The ITD concluded that it has not used the system effectively. It was recognized that greater use needed to be made of the system’s ability to predict pavement conditions in order derive the greatest benefit from the system. Such usage is expected to increase with expanded geographical coverage (which was recommended by the evaluator), improvements in accuracy, and greater confidence in and acceptance of the system. This in turn may lead to revised policies regarding use of the system.

KANSAS DEPARTMENT OF TRANSPORTATION (KDOT)

KDOT's system consists of one CPU and five RPU's which cover the Greater Kansas City area. The system was installed in 1988. Prior to obtaining its system, KDOT has relied on conventional sources such as the National Weather Service, local media forecasts, etc. for weather information during the winter storm season. Since the late 1970's, KDOT has also used the services of a private weather forecasting firm which specializes in providing information on weather and pavement conditions for highway and airport agencies. The specialized information provided by this service reportedly enabled significant enhancement in the effectiveness and efficiency of winter storm operations.

The system saw only limited use during the winter of 1988 due to installation and equipment complications. The first full winter of use was during the winter of 1989. Based on information contained on thirteen event forms (spanning the study period) prepared by the maintenance superintendent for the Kansas City area, it was concluded that the system was a success. Trust in the system information was developed after verifying accuracy with patrols. Since then, system information has been incorporated into the decision making process and has consistently resulted in reductions in personnel and material requirements. Unfortunately, the exact determination of savings was found to be subjective and difficult to quantify and was not provided.

Besides increased efficiency, the information provided has also enhanced safety via more timely treatment of potentially hazardous conditions. The results of using its system has been so favorable that KDOT is pursuing expansion to forty installations throughout the State.

MICHIGAN DEPARTMENT OF TRANSPORTATION (MDOT)

MDOT's system consists of four CPU's and eight RPU's located in various parts of the State. Use of sensors began in 1983, and the forecasting service in 1986. Access to system information by the maintenance garage supervisors is accomplished through the use of portable computers. In addition to the sensor and forecast information provided by their system, the maintenance supervisors also relied on the cable weather channel and an X-band radar unit for weather information.

During the winter of 1989, five maintenance supervisors participated in the evaluation. Information on winter maintenance event forms filled out by the supervisors were reviewed as well as the results of personal interviews with these same supervisors. Problems encountered included apparent lapses in event documentation by some supervisors and frequent equipment failures at one location (which may have contributed to the documentation problem). Use of the system varied among the individual supervisors. One carried his portable computer with him to enable access at night as well as on weekends and relied heavily on the system information in his decision making. others availed themselves of the system information only while on duty at the garage. Use of the system was apparently influenced by the reliability of the system hardware as well as the attitude of the supervisor regarding the need for supplemental information. Despite all of the above, 616 hours of personnel time was reportedly saved because of the system. Ninety-nine percent of this savings was reported by the supervisor who took advantage of the system the most.

By the winter of 1990, the equipment problems had been resolved. Although indications were that many storm events were apparently still not being reported via the maintenance event forms, the information available showed a significant savings in salt and working hours nevertheless. The reported savings of 302 tons of salt and 385 hours of personnel time is probably conservative because of the underreporting.

An attempt was made to relate the number of ice related accidents to use of the system. Accident data for the two winters showed a decrease in the proportion of ice related accidents to total accidents during the second winter. It was speculated that perhaps resolution of the equipment problems by the second winter increased the effectiveness of the system. Lack of information on the severity of the winters and on accident experience prior to using the systems made it impossible to draw a conclusion on the usefulness of the system in reducing accidents.

There was consensus among the users that the pavement sensors provided useful information which increased winter maintenance efficiency and that mor6 should be installed. Reaction to the forecasts were mixed. One supervisor found this information as useful as that provided by the sensors whereas the others found the local cable weather channel more reliable and timely and preferred it to the system forecasts. There was no specific mention of the pavement temperature forecasting feature of the system which the cable weather channel does not have.

NATIONAL PARK SERVICE, NATIONAL CAPITAL REGION (NPS)

The NPS has one RPU which is connected to the DCDPW's CPU, to which it has access. The National Park service also has access to VDOT's CPU. Similar to the DCDPW, the NPS spent the winter of 1989 familiarizing itself with the system. The first full winter of use was during that of 1990.

Based on an interview with the decision maker for the affected area, information provided by the system has resulted in more efficient use of personnel, equipment, and materials. Knowledge of pavement temperature and conditions has enabled delayed mobilization as well as earlier release of maintenance crews, and has resulted in reductions in chemical usage. Information from RPU's in Virginia and D.C. gives forewarning of approaching storms and enables more accurate forecasts. The decision maker thinks highly of the system as an aid to decision making and recommends system expansion. Currently, the system is monitored only during normal working hours except when winter storms are expected. Interest was expressed to obtaining a portable terminal which will enable better access to the system outside normal working hours.

NEW JERSEY DEPARTMENT OF TRANSPORTATION (NJDOT)

NJDOT's system consists of one CPU and four RPU's which became operational in 1985. In addition to using SSI's SCAN and SCANCAST services, NJDOT also contracted for weather forecasting services from Accu-weather Inc. and used a radar weather system from Kavouras. The CPU is located in the Region IV Maintenance Headquarters and is not monitored beyond normal working hours except under winter storm conditions. During winter storm conditions, the system is monitored and maintenance forces are activated in reaction to system warning of potential hazardous conditions. In performing its evaluation, NJDOT assigned an investigator to the Region IV Maintenance Headquarters to record the action taken in each event as it happened. This information and insights obtained through interviews with the decision maker was used to complete the maintenance event forms.

NJDOT's inclusion of pavement temperatures as a factor in the decision making process enabled delays in applying deicing chemicals and has reportedly resulted in an average reduction of one deicing chemical application per storm. Knowledge of pavement temperatures has also enabled release of snow and ice removal crews two to three hours earlier than normal. Delaying crew call-outs was also made possible with use of the system. For the 205 lane miles covered by the system, it was estimated that each deicing chemical application eliminated equated to a savings of approximately $1,100 in materials and every hour saved per crew equated to $97 in labor and equipment.

NJDOT concluded that use of the system resulted in improved forecasts for those areas covered. The system proved to be cost effective, accurate, and reliable. It was shown that use of the information provided by the system allowed improved decision making resulting in reduced personnel/equipment hours and chemical usage. It was NJDOT's opinion that it would be in the best interest of the State and the general public to expand the system to provide for Statewide coverage. Since this evaluation, four additional RPU's have been installed.

VIRGINIA DEPARTMENT OF TRANSPORTATION (VDOT)

VDOT's system began with one RPU which was connected to the DCDPW's CPU. An additional RPU was installed during 1989 and four more RPU's along with a CPU were installed in 1990. The winter of 1989 was spent becoming familiar with the system. System information was compared to previously available weather information for verification and to develop confidence in the system. Through the first three significant snow situations which occurred during the winter of 1989, information from the system was not included in the decision making process. Enough confidence was developed that information provided by the system was included in making decisions during the fourth and fifth significant snow situations. Scenarios developed for these events were subsequently used to expose personnel to the benefits of the system and train them on how to take advantage of the additional information provided by the system. Use of the system continued through nine snow or freezing rain events during the winter of 1990. The system information was relayed to various area superintendents who were the decision makers for their specific areas. Although specific cost savings for each event were not documented, actual savings were reportedly realized through use of the system. The major savings appear to be in reduced labor and hired equipment costs resulting from delayed mobilization and/or early dismissal of maintenance crews. More efficient use of these resources was made possible by more accurate forecasts as well as real time information on developing weather conditions provided by the system. Statewide system coverage is being pursued with installations under way in six counties and additional installations being considered at other locations. Sixteen portable computers were also acquired to allow direct monitoring of the system by area superintendents.

E. SUMMARY OF PARTICIPANT EXPERIENCES

A. Seven of the eight participating agencies included system information in their winter mainte nance operations decision process. During the study period, select area maintenance super visors in three of the seven user agencies were provided with portable computers to enable constant access to system information. Acceptance and use of the system varied among these supervisors. Some carried the portable with them to enable access to the system at night as well as on weekends to monitor storms as they occur and relied on them to help formulate activity plans. Others used their portables only while on duty or to monitor crew progress after the storm. The other four of the seven user agencies basically operated from a central location and monitored their systems only during normal working hours except under storm conditions when the system is monitored constantly.

B. All seven of the user agencies reported reductions in personnel, material, and/or equipment usage during winter maintenance as a result of information provided by the system. The degree of benefit realized varied with the manner in which the system was used. One agency which had five maintenance supervisors with portable access to the system attributed ninety-nine percent of its reported savings to the one supervisor who took advantage of the system the most.

C. Four of the participating agencies reported attempts to determine the safety benefits offered by the system. Although actual reductions in the number of accidents could not be quanti fied, there was consensus that use of the system enhanced safety by enabling more timely treatment of icing conditions. The consequent decrease in the number of black and glaze ice occurrences results in a concurrent decrease in the number of ice-related accidents.

D. One agency did not include system information in its winter maintenance decision process for several reasons:

1. The route on which the sensors were located had a high priority for winter maintenance and the decision makers “expressed an unwillingness to rely entirely on the ice detection system as a basis for crew response.” In fact, State policy prohibited use of the system as the sole factor in dispatching by supervisors. In any case, two crews gave the study section continuous attention during the winter due to its importance.

2. Current State policy dictates that crews be out on patrol by 4:00 AM, two to three hours before the first system report is printed out each day. The system is monitored only during normal working hours.

3. The foremen responsible for the study section were also responsible for other routes. There fore, “reliance of these foremen on the ice detection system for condition reporting would not mean that they could save man hours, since the crews must be out to report on the other routes anyway.”

4. Equipment malfunctions over the last two winters resulted in a lack of confidence to rely on the system for scheduling.

5. The current system was too geographically limited. The majority of major storm fronts moved in from the west whereas the RPU's were concentrated in the east.

E. All eight participating agencies expressed general satisfaction with the accuracy of the sensor and forecast information.

F. All eight participating agencies either experienced or recognized the potential benefits the system can offer when used effectively. All are either in the process of expanding or have expressed interest in expanding their system to broaden the area of coverage.

G. Common to all participants was the need for a learning period during which users can develop a feel for and trust in the system. For some, this was a relatively quick process with full acceptance by the users. For others however, acceptance was slow in developing and was at times fragmented. This was more of a problem in those agencies where many decision makers are involved, existing policy conflicts with effective system utilization, or equipment problems have been experienced.

MULTISTATE REGIONAL ICE DETECTION AND HIGHWAY WEATHER INFORMATION SYSTEM

As part of this project, the Metropolitan Washington Council of Governments (COG) performed a study on the complexities of organizing a tri-state, multi-level jurisdictional approach to a regional ice detection and highway information system. The focus was on the metropolitan Washington, D. C. region which includes the District of Columbia, and portions of Maryland and Virginia. Optimal coverage for the Washington metropolitan region would encompass 18 cities and counties in these three States (including the District of Columbia).

Along with benefits of equipment savings, enlarged area of coverage, and improved decision making which can be realized from a regional system, the Washington Metropolitan COG also identified a number of complications which were encountered in establishing such a system. one obstacle that had to be overcome was acceptance of the new technology by all the entities involved. Officials at all levels of government had to be convinced that the system will enable better decisions and result in operations cost savings. With software licensing and basic hardware costing tens of thousands of dollars, funding was another obstacle, especially where local governments were involved. Finally, the problem of integrating individual sensors into a regional network to avoid having a group of merely autonomous units had to be overcome. Due to the proprietary nature of the system used, integrating individually purchased systems of the same manufacturer into a network appeared to be the only way to achieve the desired regional coverage without infringing on any legal rights of the vendor. Thus, there could be no master CPU collecting information from all the individual CPU,S. If information is to be exchanged',, it has to be done by a direct phone line from one CPU to another or by a teleconference of sensor users.

The Washington Metropolitan COG recommended consideration of the following when contemplating establishment of a regional road sensor network:

? The development of a regional sensor network should be coordinated by a single regional entity, such as a COG, planning commission or like organization, with all parties to the network participating in the process. This will preclude one jurisdiction from making planning decisions for another, and ensures that the planning process takes place at an objective, extra-jurisdictional level.

? Jurisdictions/agencies that participate in a regional sensor network should be fully aware of the benefits that can accrue to them through regional information sharing.

? Operational advantages and overall cost effectiveness of a regional system using state-of-the-art technology should be demonstrated by a pilot project to ensure that all participants fully appreciate the potential benefits of regional networking.

? A long lead time is needed to justify, budget, manufacture, install and test a sensor system before it becomes operational.

? Vendor proprietary requirements may dictate that a regional network be developed from a series of systems purchased individually by participating jurisdictions/agencies, as opposed to a single system purchased and controlled by a single buyer for the entire region.

? A network expansion plan should be an integral part of the overall planning process so that sensors can be assigned to CPU's as the network grows.

CONCLUSIONS

A. Proactive use of ice detection and highway information systems to aid in planning winter maintenance operations can:

1. result in reductions in personnel, material and equipment needs,

2. enable more timely treatment of icing conditions and reduce the potential for accidents by reducing the incidence of black and glaze ice pavement surface conditions,

3. result in reductions in the amount of corrosive or environmentally harmful chemicals used for snow/ice control.

B. A learning period is required for users to develop a feel for and trust in the information before the system is used effectively. Realization of the full benefits from the system will be gradual.

C. Acceptance and use of the system was influenced by the reliability of the system hardware as well as the attitude of the individual user regarding the need for supplemental information.

D. Effective system location and a well thought out process on how to incorporate the new information into the decision making process is crucial to success. Existing winter maintenance policies and practices may require adjustment to realize system benefits.

E. A regional system which allows for information sharing between jurisdictions provide benefits of equipment savings, enlarged area of coverage, and improved decision making.

F. Interjurisdictional cooperation and a systematic approach which recognizes and addresses the complications associated with establishing a regional system network are key to success.

G. Ice detection and highway weather information systems for improved highway operations and safety are considered to be proven technology.

RECOMMENDATIONS

A. Prior to obtaining a system, a thorough evaluation should be made to determine the location(s) for remote sensors which will provide the best information. Strategies on how best to use the new information should be formulated. Existing policies and practices should be reviewed to determine compatibility with the system. These policies and practices should be modified as necessary to encourage proactive use of the system.

B. Potential users at all levels should be made aware of the usefulness of the system through demonstrations and be trained in using the information available for maximum benefit.

C. Current and potential users of ice detection and highway weather information systems should explore the possibility of establishing regional networks which enable information exchange.

D. Future installations of ice detection and highway weather information systems for improved highway operations and safety should be accomplished using normal Federal-aid procedures and funds.

Return to Table of Contents