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Benefit/Cost Study of RWIS and Anti-icing Technologies

FINAL REPORT

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ABSTRACT

To facilitate implementation of technologies identified in the Strategic Highway Research Program (SHRP), the American Association of State Highway and Transportation Officials (AASHTO) formed the AASHTO Task Force on SHRP Implementation. The Task Force formed AASHTO Lead States Teams for seven promising efforts, one of which was the snow and ice control strategy of anti-icing and the use of road weather information systems (RWIS). The AASHTO Lead States Team for Anti-icing/RWIS identified the need for documenting the benefits and costs associated with the application of anti-icing/RWIS technologies. National Cooperative Highway Research Program (NCHRP) Project Panel SP 20-7, "Research for AASHTO Standing Committee on Highways," established Project 20-7, Task 117 to document these benefits and costs. This report describes anti-icing and RWIS research, implementation efforts by highway agencies, and summarizes the current practice of anti-icing technology. The benefits and costs of anti-icing and RWIS, as reported in the literature and supplemented with information provided in interviews of highway professionals are outlined. Conclusions and recommendations regarding anti-icing and RWIS use are also presented.

CHAPTER 1
INTRODUCTION

In 1987, the United States Congress, with support from the Federal Highway Administration (FHWA) and the American Association of State Highway and Transportation Officials (AASHTO), approved a five-year research program that was to focus on products and procedures that had high potential for improving the safety, performance, and durability of the nation's highways. The research, formally titled the Strategic Highway Research Program (SHRP), was performed under the National Academy of Sciences and involved many state transportation agencies.

Once of the four areas of focus for the SHRP program was Highway Operations, which included research into snow and ice control as well as other maintenance activities. Although some of the projects were more typical research efforts, two snow and ice control projects involved the investigation of innovative practices. Up to this point, snow and ice control had been generally reactive in nature. When snow began accumulating, agencies would typically perform mechanical removal of snow accompanied by deicing with chemicals or traction enhancement with abrasives. Some agencies did use chemicals to try to prevent snow and ice from compacting and adhering to pavement [1].

This reactive nature of snow and ice control was becoming increasingly costly as traveling public expectations for road conditions increased. Large amounts of chemicals, especially road salt (NaCl), were frequently used in areas where they were allowed or favored by agency practices. When chemicals were not used, abrasives or abrasive and chemical mixtures were used. The costs for increased use of chemicals and inefficient plowing due to compact snow or abrasive use began to rise. But there were also environmental considerations.

Road salt was seen as contributing to decreased water quality and to vegetation damage. Using abrasives incurred cleanup costs and was identified as reducing air quality. Alternative chemicals were frequently significantly more costly than road salt. In general, the cost of snow and ice control was increasing as agencies worked to improve their level of service. Some help in reducing costs evolved out of the SHRP project.

One of the SHRP projects, SHRP H-207, "Storm Monitoring/Communications," investigated the use of road weather information system (RWIS) technologies to support snow and ice control decision making. Another project, SHRP H-208, "Development of Anti-icing Technology," investigated the proactive use of chemicals for snow and ice control. This proactive chemical use is the snow and ice control strategy now called anti-icing. Nine state highway agencies (SHAs) participated in this research. The results of H-207 were published in SHRP-H-350 [2] and H-351 [3]; the results of H-208 were published in SHRP-H-385 [4].

The SHRP Program ended in the early 1990s, but a need existed to continue some long-term research and also to ensure that identified products would be implemented into highway operations. Further anti-icing research was identified as one of the needs, and the FHWA initiated Test and Evaluation Project 28, Anti-icing Technologies, which added SHAs to the research effort [5].

Recognizing the need to provide a boost to the implementation of SHRP research, AASHTO established a Task Force on SHRP Implementation. To ensure that the experiences of the participating SHAs can be shared with all states, the Task Force created the "Lead States Program." The program targeted seven technology areas, one of which was Anti-Icing/Roadway Weather Information Systems. Seven SHAs participated in the anti-icing/RWIS areas: Colorado, Iowa, Minnesota, Nevada, New York, Pennsylvania, and Washington. There was also participation from vendors and consultants.

The role of the Lead States Program was transferred to the AASHTO Technology Information Group in late 2000. The anti-icing/RWIS program transitioned into the AASHTO Subcommittee for Maintenance's task force for snow and ice control. Continued implementation will be coordinated through the AASHTO Winter Maintenance Policy Coordinating Committee (WMPCC) and the AASHTO Snow and Ice COoperative Program (SICOP).

To encourage use of anti-icing/RWIS technologies, there is a need to assess their benefits and costs. NCHRP Project 20-7, Task 117 was initiated to address this need. Results of this assessment are documented in this report.

CHAPTER 2

EARLY ANTI-ICING/RWIS RESEARCH

The following sections provide a brief description of early research in this country into road and weather information technology and the snow and ice control practice of anti-icing.

RWIS

Although the use of sensors to detect snow and ice control related pavement conditions had been tried in the highway environment, most sensors were unreliable and there was little effort to expand applications. However, in the early 1970s, a system was developed by Surface Systems, Inc. (SSI) and installed in airport runways and ramps (conversation with surface sensor inventor and original owner of SSI, Wilson Overall). In the early 1980s, this same technology was tested in the highway environment and proved to be successful (conversation with Robert Hart, SSI).

In the mid-1980s, a few SHAs, such as Minnesota, Pennsylvania, New Jersey, Washington, and Wisconsin began testing pavement sensors. Research into the use of this technology in these states showed that snow and ice control decision makers could make their operations more efficient and effective by using weather and pavement condition information. Especially important was the ability to monitor pavement temperature and to compare temperatures with forecasts of pavement temperatures. In the past, snow and ice control personnel monitored air temperature and forecasts thereof. With pavement surface and subsurface temperature information now available, their attention was soon placed on the roadway, which is what has the major influence on how snow and ice behave on the pavement. In the investigation, the research considered all aspects of weather information, such as forecasts and communications, as well as in-road and roadside sensors, to be a part of RWIS [2].

This research pointed to potential savings in labor, equipment, and materials by making more intelligent decisions. Parallel research in Europe through the European Community's COoperation in Science and Technology (COST) program was also investigating RWIS technology. The COST 309 project provided additional benefits to using RWIS [6]. This project documented indirect benefits that resulted from more effective and efficient snow and ice control, such as reduced accidents and fatalities, increased mobility, and reduced economic costs related to snow and ice control.

A benefit/cost model developed during the research on RWIS technology indicated a benefit/cost ratio of up to 5 for RWIS implementation. Also, the use of a weather index, which related costs of snow and ice control to weather severity and frequency of occurrence of snow and ice events, showed snow and ice control costs are reduced when as RWIS technology is implemented [2].

ANTI-ICING

In the early 1990s, the concept of using RWIS information to support more efficient and effective decision making created interest in investigating the proactive use of chemicals to perhaps prevent snow and ice from bonding to pavement. Chemicals have been used in snow and ice control to melt snow and ice and to facilitate the removal of the snow or ice by plowing.

Indications were that chemicals could be used in conjunction with weather information to make timely decisions to prevent the bonding of snow and ice. Five times more energy is required to remove snow and ice from the roadway after a bond has been formed. Preventing bonding could result in more timely removal of snow and ice and reduce the amount of deicing chemicals used.

Based on this potential, research was initiated to investigate the concept of anti-icing. This project investigated for two years the use of chemicals in anti-icing. Anti-icing and conventional treatments were analyzed under various weather conditions at different geographical locations the use of anti-icing procedures by SHAs in nine states: California, Colorado, Maryland, Minnesota, Missouri, Nevada, New York, Ohio, and Washington. Results of the research indicated that cost savings to motorists as well as the SHAs were possible and the use of chemicals can be reduced. Also, results indicated that anti-icing does not work under all situations. The success of anti-icing is sometimes a result of individual interest and initiative, and training of personnel and good weather information are key. The project also recommended that further investigation is necessary to document the weather, traffic, and other conditions under which anti-icing can be used. In addition, it was recommended that further investigation is necessary to look at the use of various liquid and solid chemicals.

In the mid-1990s the FHWA undertook a program to foster SHA implementation of the technologies and practices determined to be effective by SHRP research. FHWA initiated a test and evaluation program to investigate anti-icing. FHWA Test and Evaluation (T&E) Project 28 used much of the same approach used in the earlier research and conducted experiments at different sites under various weather conditions using different anti-icing and conventional chemical treatments. In addition to the nine states that participated in the earlier research, T&E 28 enlisted six additional states: Iowa, Kansas, Massachusetts, New Hampshire, Oregon, and Wisconsin.

The results of two years of data gathering from T&E 28 reinforced the hypothesis that pavement temperature is a key element when conducting anti-icing. Also important, in order of precedence, were precipitation character, and traffic volume. The research also indicated that anti-icing can provide a higher level of service, that careful consideration needs to be given to current and expected conditions when applying chemical treatments, especially liquids. Pretreatment ahead of a storm or at its onset essentially buys time and a return for further treatment in a timely manner is required to prevent conditions from deteriorating. The role of abrasives is limited within a snow and ice control program that is successfully conducting anti-icing. Cost savings are possible with anti-icing, but more importantly, the attainment of a higher level of service using the same or less materials, or providing the same level of service with fewer materials are all possible.

One of the important outcomes of the T&E project was the preparation of the "Manual of Practice for an Effective Anti-icing Program." [7]. While the T&E 28 investigation was relatively comprehensive, the project recommended that further evaluation be conducted to validate the effectiveness and efficiencies provide in the Manual.

CHAPTER 3

AGENCY ANTI-ICING UPDATE

Using information obtained from the SHRP H-208 principal investigator and from the T&E 28 Project Field Evaluation Report [5], contacts were attempted with participants in the two research projects. Some of the personnel that participated in the research no longer work for the agencies and some of the remaining personnel had little or no knowledge of the research. Following are brief paraphrases of conversations with personnel who were contacted. Any benefits documented in these responses are also included in the discussion of benefits in Chapter 5.

NEW YORK STATE DOT

NYSDOT conducts anti-icing by virtue of their 24-hour staffing for snow and ice control. They called it "just-in-time" icing. They put down solid chemicals at the storm outset. Liquids are not of much benefit because of their staffing levels and their ability to respond quickly. The real benefit is to just keep plowing, apply chemicals as snow continues, and then make one application at the end of a storm and they are "home free." The just-in-time treatment prevents the bond from forming and allows for plowing to start and to keep a mealy mixture that can be continuously plowed. In other words, they are conducting anti-icing, but under a different name.

In an interview with another maintenance person, it was indicated that the benefits of anti-icing were fairly clear … preventing the bonding of snow and ice. It's a function of the kind of storm. Also, the types of chemicals used are important. The person interviewed indicated that right now they are not conducting anti-icing. They have reverted back to granular salt; they are not using liquids. "It's a result of problems with personnel and people not thinking outside the box." A new RWIS contract in place may help out anti-icing usage. (This is a common misconception. The use of granular salt in a just-in-time mode is anti-icing. Many snow and ice control practitioners believe that anti-icing is pretreatment only.)

A third individual indicated that in the T&E 28 test area they now use $MgCl_2$. They have expanded to bridge decks for pretreatment, based on forecasts of frost conditions. They have special equipment using ground speed control. He indicated that the benefits of anti-icing and pretreatment are to buy time for personnel response. It has cut down on overtime and they attain bare pavement quicker … better level of service. The savings in overtime are a big bang for the buck.

OHIO DOT

During T&E 28, people thought it was a liquid chemical experiment trying to get chemicals down before a storm. They are not doing pretreatment now. They only on occasion do prewetting of chemicals but in general their vehicles aren't set up for it. They have some liquid $CaCl_2$ and use overhead spray bars to prewet a load in a dump truck. They have to be careful because if they do this, they have to dump the entire load if it is not used. However, they probably use less salt when anti-icing and get the same skid numbers. Also, they are able to

provide the same level of service with less salt. They are in the process of getting new dump trucks with saddle tanks so they may do more prewetting but not any more pretreatment.
A second person said that they were not able to relate costs of anti-icing or cost savings from anti-icing. Benefits included patrols reporting roads were generally in "pretty good shape." The biggest benefit is the ability to buy time at remote locations. In one area in the far NW of the county, on one 2-lane, steep grade, 90-degree curve road segment, they reduced accidents from 12 per annum to one. They were also able to prevent black ice on bridge decks.

COLORADO DOT

CDOT is pretreating with $MgCl_2$ and another commercial chemical. They are also pretreating stockpiles. There is some pretreatment for frost East of Grand Junction. Since the research projects, they have broadened the use of anti-icing. There is a great deal of anti-icing work in Denver. CDOT is using liquids from Pueblo to Wyoming on I-25, from East of Denver to Utah on I-70, and in non-air attainment areas. It's a factor of 10 more anti-icing. They have no documentation because they don't know how to do it. They know anti-icing improves the level of service and reduces the amount of abrasives. Also, maintenance personnel are off the roads quicker at the end of a storm. It hasn't actually reduced cleanup costs because they still cleanup the same way. But there is less sand to clean up. Anti-icing does cost more but they can't document the savings in sand. The CDOT spokesperson suggests that all agencies "just do it."

NEW HAMPSHIRE DOT

During the research they used Potassium Acetate (KA) but it is expensive. They have opted not to do any more anti-icing, whether for bridges or roads. They have used Ice Ban and $CaCl_2$ to prewet sand, and a couple of districts are prewetting solids. This appears to be another instance of confusing pretreatment and anti-icing terminology.

IOWA DOT

The important part of T&E 28 was that it got us started by providing some equipment (an Epoke spreader) that we would not have gone after ourselves. The project essentially got us started in anti-icing.

A second person said that Iowa DOT has an extensive pretreatment and anti-icing program, but they do a poor job of documenting and therefore can't quantify cost savings. They do know that they've reduced overtime 40% in the last three years and have cut a $50K cost of sand disposal to near zero now. General benefits include not as much damage to infrastructure, less insurance claims, virtually no bonding of snow/ice to pavement. Stopped road frosts, and stopped blowing snow problems.

CALIFORNIA DOT

During the research, the Mt. Shasta region was the only area using liquid chemicals. Almost everywhere, liquids are now in use. However, there have been no studies or documentation since the early research. They started out using a 3,000-gallon tanker with a spray bar applying 25

gal/ln-mi. They now use (on secondary roads) slip-in tanks for 4-yd trucks. They have cut back on the use of abrasives which has resulted in less cleanup of drains. They now clean every other spring, and they have cut "way back" on sweeping along berms. Pretreatment is now routine maintenance because they provide a better level of service. They have only had to close I-5 in the Mt. Shasta area once in seven years thanks to anti-icing. The practice has also expanded to other areas. Along I-5 at Grapevine (south of Bakersfield) they now have no road closures whereas in the past they've had about six per year. They have tried salt brine in some surrounding areas but have had refreeze problems.

WASHINGTON STATE DOT

Prior to the SHRP research they used salt at 10% concentration in the sand piles. The SHRP project provided money that allowed them to expand their capabilities. They transitioned first to prewetted salt, then transitioned to liquid CMA. They now handle all icing situations with liquids. They pretreat known trouble spots and they stay with liquids as long as snow is not accumulating. They are also starting to use Magnesium Chloride. The pretreating with CMA has reduced corrosion and has allowed them to provide a better level of service in more areas. The also believe they have long term gains that are estimated from lack of cleanup requirements, reduced accidents, and minimized Endangered Species Act concerns (which are a result of abrasives ending up in and contaminating fish habitat).

The author also attended a post-season winter wrap up session in the North Central Region (NCR) of the Washington DOT. Following are paraphrased comments related to their experiences with the 1999-2000 winter where they are attempting to implement anti-icing and to document its benefits. The NCR is using a liquid mixture of 30% Calcium Chloride and Ice Ban.

The following is a general summary of the benefits noted by the NCR. Each Area Maintenance Supervisor provided an assessment of anti-icing based on experiences in the Area during the Winter of 1999-2000 [8].

- Better level of service,
- Fewer accidents,
- Less sand usage,
- Less time on equipment,
- More positive feedback from public,
- Contingency shifting yielded more productive maintenance over the winter,
- Happier environmentalists,
- Overtime went to regular employees, not temps, and
- Better personnel management with regional effort and initial training:
- More people involved,
- More and better interaction,
- Greater acceptance,
- Better inter-sectional coordination, and
- Regional/national "notoriety.

It should be noted that nearly all agencies indicated that RWIS is an extremely important tool for anti-icing, although some are doing it without the benefit of either real-time access or access in their immediate area. The important RWIS information, the benefits of which are also shown in Chapter 5, are forecasts of precipitation onset, the type of precipitation, and its expected duration. These forecasts need to be combined with observed and forecast pavement temperature. As one person indicated, "you don't want to anti-ice if the pavement temperatures are going to be too low." One parameter available from RWIS, but never mentioned – even in the context of frost – is the dewpoint. The combination of pavement temperature and dewpoint and their forecasts are the information ingredients for frost (and black ice). This is primarily a training deficiency, because dewpoint is not well understood by most people in any context. But the bottom line, as was reported from the Ohio DOT, is that "knowing when to salt or not is important … and you get that information from RWIS."

CHAPTER 4

CURRENT ANTI-ICING PRACTICES

From interviews of highway agency personnel who are conducting and/or managing anti-icing programs, as pointed out in some responses from agencies in Chapter 3, there is some misunderstanding about anti-icing and deicing. Both anti-icing and deicing are snow and ice control strategies that use chemical freeze point depressants.

ANTI-ICING

The strategy of anti-icing involves the use of chemical freeze point depressants to prevent a bond from forming between pavement and snow or ice. There is a frequent misunderstanding between the term pretreatment and the strategy of anti-icing. Pretreatment is just one of the tactics that can be employed when anti-icing.

Some personnel believe the use of solid or prewetted solid chemicals in other than a pretreatment mode is deicing. However, the strategy of deicing involves the use of freeze point depressant chemicals to break a bond that has formed between snow or ice and the pavement. If no bond is formed, these chemicals can still be used to prevent the bond from forming and the strategy is therefore anti-icing.

A recent survey by the AASHTO Lead States Team for Anti-icing/RWIS documented that 35 states out of 39 that responded are conducting anti-icing [9]. It is possible that a higher percentage of states are conducting anti-icing if the broader definition is considered.

There are various tactics that can be employed when anti-icing. Some of these include:

- Pretreatment using liquid chemicals before a winter weather event. The liquid can be applied to the pavement sufficiently far in advance so that it dries and leaves a solid chemical residue that will form a chemical solution upon precipitation;
- Pretreatment with the application of liquid chemicals, frequently on a semi-weekly basis, to bridge decks or other potential frost areas, to prevent frost formation. Liquids are sometimes applied near midday so that there is sufficient time for the liquid to dry. They can also be applied just prior to the time frost is expected to form. Such applications are also made based on forecasts of the occurrence of frost.
- Pretreatment using prewetted solid chemicals. This tactic can be used when pavement temperatures are or are expected to be too cold for the application of liquid chemicals.
- Pretreatment with solid chemicals. This tactic is usually reserved situations where precipitation has started and the wet pavement surface will aid in the retention of the solid chemicals on the pavement.
- Application of prewetted solid chemicals or solid chemicals at the onset of a storm. The may or may not follow a pretreatment. The pretreatment is used to buy time before an application of the solid materials is required.
- Application of prewetted solid chemicals or solid chemicals during a storm. Such an application is usually made after the slush or loosely packed snow or ice is plowed and not

immediately prior to plowing. The purpose is to keep the snow or ice on the surface workable throughout the storm.

Research is currently underway in National Cooperative Highway Research Program (NCHRP) project 6-13 to investigate the most effective tactics under varying conditions and using different chemicals. It appears, however, that the most widely used chemical for anti-icing is Sodium Chloride (NaCl), either as salt brine, prewetted road salt or dry road salt. Applications rates for pretreatment using liquids vary by agency, but somewhere close to 45-50 gal/ln-mi is representative. This places about 100 lb/ln-mi of sodium chloride on the surface using a 23.3% solution of salt brine. Care needs to be taken to monitor the dilution potential of the solution once precipitation is initiated.

Solid chemicals are frequently prewetted with salt brine at the rate of 8-12 gal/ton when the brine is applied at the spinner or tailgate. Little is known, however, about the amount of liquid that actually is retained on the solid chemical and it may be necessary to increase that rate. Solid chemicals are applied in pretreatment at about 100 lb/ln mile and when deicing with colder pavement temperatures or during heavier snow events at about 200 lb/ln-mi.

Salt and salt brine are being used frequently because of the relatively low cost. Salt brine can be made for as little as $0.03/gal and in large quantities relatively quickly. Figure 1 shows salt brine storage tanks in use by the Iowa DOT. Each storage tank holds about 5,000 gal while the brine maker can produce about 4,000 gal/hr.

Figure 1. Brine Storage Tanks in Use by the Iowa Department of Transportation.

Equipment used in anti-icing has evolved significantly through the years since the anti-icing research projects began in this country. Figures 2 through 5 provide some examples of equipment in use.

Figure 2 shows a 2700-gallon salt brine trailer being towed behind a spreader. Iowa DOT uses this equipment to both pretreat with brine and to wet road salt applied at the spreader. This practice is a derivation of prewetting materials at the spreader. One Iowa DOT garage has devised a chute for applying prewetted chemicals. The chute directs salt, which is prewetted at the top of the chute, into a narrow path on the road surface and functions much like a zero-velocity spreader.

Figure 2. Trailer with 2700-Gallon Tank for Salt Brine.

Figure 3 shows a 5000-gallon tanker used in Interstate highways in Iowa. Iowa acquired the tanker from Army surplus and were able to outfit the tanker for anti-icing for less than $15,000. Washington DOT has indicated they are putting a 6,000 gallon tanker into service in the North Central Region for the 2000-2001 Winter.

Figure 4 shows examples of prewetting systems for spreaders. Figure 4a shows saddle tanks alongside a hopper spreader, while Figure 4b shows a rear-mounted liquid dispenser mounted above a tailgate spreader.

Figure 3. 5000 Gallon Tanker for Brine Application on Interstate Highways.

4a.

4b.

Figure 4. Examples of Prewetting Equipment Mounted on Spreaders. Figure 4a: Hopper with Saddle Tanks; Figure 4b: Tailgate Spreader. (Photos courtesy of Swenson Spreaders)

Anti-icing is not just confined to over-the-road equipment. Recently advanced anti-icing technology has produced in-pavement and alongside the road automated or manually controlled anti-icing systems. These can be installed in roadways or bridge decks as well as mounted alongside either. Figures 5a and 5b show examples of such spray systems. This type of system is currently being evaluated by a number of highway agencies.

5a. **5b.**

Figure 5. Examples of Fixed Anti-icing Spray Systems. Figure 5a. In-road spray nozzle. Figure 5b. Spray nozzles mounted in barriers alongside the roadway. (Photos courtesy of Odin Systems)

USE OF RWIS

Maintenance supervisors use RWIS information to decide what strategies and tactics to employ for snow and ice control. They use forecasts to determine when precipitation is to begin, the type and amount of precipitation that will occur, and the duration of the expected event. Initially, the information is used to call out personnel or implement snow and ice control work schedules. They also decide what kind of equipment will be needed and what materials need to be loaded. Pavement temperature and pavement condition data are used to determine the effectiveness of chemical applications, the need for additional applications, and the chemicals to use. Ancillary information such as radar data can assist in determining when precipitation is likely to occur and when the event is nearing completion so that clean up activities can be planned.

As pointed out in the anti-icing research project, weather and pavement condition information from an RWIS is critical to the successful conduct of anti-icing. First and foremost, the temperature of the pavement, along with the concentration of any chemical solution on the pavement, will dictate what tactics need to be employed. The Manual of Practice for an Effective Anti-icing Program clearly identifies pavement temperature as a consideration for selecting tactics [7].

A further consideration for RWIS arises when using the global RWIS concept that includes ancillary weather data and weather and pavement condition forecasts as part of RWIS. The character of precipitation is the second most important impact on anti-icing. Personnel anticipating conducting or who are conducting anti-icing need to pay attention to the current and expected character of precipitation in relation to the pavement temperature and the anti-icing tactics selected. This applies to storm onset, conditions within a storm, and the duration of a storm. All of this information is needed to assess the needs for treatment as anti-icing continues. It is also helpful if ancillary data such as weather radar are available so that a decision maker can examine the character of precipitation within a storm. Snow typically occurs in bands and the

bands of snow sweeping over an area can sometimes be well represented on radar. Of course, upstream RWIS data and input from field personnel are also helpful.

As the decisions related to conducting anti-icing require good RWIS information, so do the decisions not to anti-ice. There are circumstances where anti-icing is not appropriate. If pavement temperatures are expected to be below a level specified for the use of liquid chemicals, then pretreatment with liquids should not be done. When blowing snow is expected, roadway surfaces should be dry, not wet. Again, pretreatment with liquids is not appropriate. And when pavement temperatures are expected to become very cold, leaving a pavement bare and wet is not a good choice and abrasives mixed with chemicals may be the strategy and tactic of choice.

CHAPTER 5

BENEFITS/COSTS OF ANTI-ICING/RWIS

Determining whether or not procedures are effective or there are benefits to performing certain procedures can be a difficult and involved process. Agencies have little guidance on how to document benefits. Opportunities to document benefits range from comparing costs when using different strategies and tactics to evaluating the results of procedures using measures of performance, such as level of service goals. No agency contacted had developed a formal performance measurement program that could be used to assess the benefits of anti-icing.

Pennsylvania DOT is conducting an anti-icing benchmarking project and contacted many agencies to determine how they are documenting results of their anti-icing programs. Table 1 lists how the surveyed agencies measure results [10]. There is a reference in the Table to TAPER Logs. These are logs used by some agencies to document snow and ice control

Table 1. Agency Methods of Measuring Results from Anti-icing Programs

Percentage of Agencies Using the Method	Method for Assessing Results
44	TAPER Log
21	Customer Surveys
6	Media
8	Accident Data
17	Complaint Data
69	Visual Observation
71	Employee Feedback
17	Other:
Unknown	Various spreadsheets & reports produced locally
Unknown	Log, post applications results
Unknown	Log
Unknown	Use of control sections
Unknown	Post storm assessments

performance. TAPER is defined as follows: T = lowest pavement Temperature expected; A = Application rate; P = Product being used; E = Event characteristics; and R = Results.

In a similar manner, agencies contacted in the Pennsylvania DOT project were asked how they evaluated the effectiveness of their program. Following is a listing of the various responses. This listing shows the variability in methods (and in some cases inability) to document anti-icing effectiveness, much less the benefits or costs associated with anti-icing.

- Visual observation, employee and foreman input, comparison
- No existing evaluation system
- Observation at treated areas
- Visual examination of areas applied
- Overall driving conditions, roadway surface end result
- Material usage
- Accident data, employee feedback, visual observation
- Ease of cleanup after storm/taper log/ accident reports
- TAPER log
- Tests between treated & untreated sections
- Only used 20,000 gal to date. Need more experience
- Only applied 2 or 3 times. Not enough data
- Last year was the first year for salt brine. Track better this year.
- Various reports & spreadsheets
- Short term program effective
- Monitor employee feedback
- Not evaluated yet
- Not much success, similar data is (sic) hard to collect
- Could not evaluate last year, better evaluation this year
- Visual comparison to adjacent roads
- Keep pavement wet (especially bridges) snow/ice will not bond to pavement. Keep traffic volume moving with out accidents.
- If it melts snow on pavement it is effective
- Visual and driver updates from complaints
- Not enough experience, results look good
- Winter not bad enough yet to evaluate
- Employee feedback & visual observation
- Results achieved vs. cost (benefit/ cost analysis)
- Assistant managers & foreman input/ trial and error
- Comparison of treated to untreated
- Evaluation is done through foreman/employee feedback
- Foreman/employee feedback
- Length of time pavement stays ice free after storm begins
- Overall employee feedback from the actual effects
- Excellent
- Visual observation by our county assist, foreman, and operators

- Time before treatment is needed. Cost savings/material usage
- Material usage, employee feedback, visual observation
- Too new to evaluate

FHWA Focus Articles and Technical Briefs available from the FHWA Winter Maintenance Virtual Clearinghouse were reviewed for RWIS and anti-icing reports. The FHWA Technical Briefs are available on the Internet at http://www.fhwa.dot.gov////////winter/briefs/briefs.html . Inputs were also obtained from reports from the Pacific Northwest Snowfighter Conference in British Columbia, and preprints from the Transportation Research Board's International Symposium of Snow Removal and Ice Control Technology in Roanoke, Virginia. Documentation was also obtained from winter 1999-2000 post season debriefings from the Iowa State Department of Transportation [11].

BENEFITS OF RWIS

Following is a combined listing of general benefits reported for RWIS. The listing includes comments from the examples in Chapter 3 as well as the other sources listed above. As is the case with the Pennsylvania benchmarking project, agencies could describe benefits qualitatively, but did not have quantitative results.

The major categories are listed in order of the number of comments received. Some of the benefits listed could be grouped in more than one category. The benefit stated most often, based on perceptions of the maintenance people, was a resulting safer travel for the motorists when agencies have access to RWIS information. Obviously any improved safety results in part from the maintenance responses. The benefit stated second most was the ability to reduce costs or save money agency money. In most cases, except for the comments in the FHWA Technical Briefs, agency personnel could not specify quantitative cost savings because they don't know how to do it. In each case, the line item benefits shown as bulleted items were individually stated and grouped for this presentation.

Level of Service.

- Safer travel
- Improved driver information
- Help for local agencies, public service functions (through sharing data)

Cost Savings

- Save agency money
- Reduce staff/equipment requirements
- Reduce use of salt
- Reduced patrolling

Maintenance Response to Information

- Get the right equipment and materials at the right place at the right time
- Assist with crew scheduling
- Increased efficiency
- Implement better response strategies
- Helps make maintenance more effective
- Helps with decisions to “do nothing” when appropriate

Environmental Quality

Results from reduced salt usage, which is also included in Cost Savings.

Indirect Benefits

- Shorter travel times
- Reduced accident rates
- Reduced workplace absenteeism
- Less disruption of emergency services

Other Benefits

- Reduced wear on equipment and bridges
- Help in paving operation planning (other than winter maintenance)
- Assistance in avalanche risk assessment

Note that for level of service no performance related level of service conditions were mentioned, such as bare pavement, although TAPER Logs refer to results and service level goals.

BENEFITS FROM ANTI-ICING

As with RWIS, only qualitative statements of benefits from anti-icing were obtained. Following are examples of benefits stated by agencies for implementing an anti-icing strategy. The major categories are listed in order of the number of comments. Some of the benefits listed could be grouped in more than one category. The benefit stated most often was improved safety for the motorists when agencies implement anti-icing.

Level of Service.

- Safer travel
- Improved driver information
- Reduced insurance claims
- Reduced accidents
- Reduced snow and ice bonding
- Reduced number of road closures

Cost Savings

- Reduced costs
- Reduced chemical usage
- Reduce abrasives usage
- Reduced overtime
- Less time spent clearing roads
- Less cleanup, both for drains and for sweeping.

Maintenance Response to Information

- More efficient plowing
- More efficient use of materials
- Buys time for response

Environmental Quality

Improved environmental quality results both from reduced chemical and abrasives usage. The reduced chemical usage means fewer chemicals are invading roadside vegetation, aquifers, or watercourses. The reduced abrasive usage results in improved air quality in areas where abrasives have been identified as a contributor to air pollution, and in siltation of watercourses. The latter has an impact in streams where some species of fish have been identified as endangered under the Endangered Species Act.

Indirect or Other Benefits

- Less damage to cars, pavements
- Reduced equipment wear

Negative benefits have also been attributed to anti-icing, but these occur on a case-by-case basis and in most cases can be avoided with the proper use of RWIS information. Following are negative benefits that can occur.

- The use of liquid chemicals under high wind conditions can cause snow to adhere to a roadway when if the pavement were left dry, snow would just blow over the road;
- Pretreating roadways with liquid chemicals can lead to freezing surfaces if the pavement temperatures drop below certain thresholds or if cycle times do not allow for just-in-time treatments with solid or prewetted solids following the pretreatment;
- Pretreating with liquid chemicals has led to slippery conditions. Research is underway to try to identify the conditions under which such slipperiness occurs;
- Level of service problems can arise at garage, area, district, agency, or state boundaries. When one agency or unit conducts anti-icing and an adjacent or collocated agency does not, motorists may have to travel from bare or wet pavement to icy or snow-covered roadways when they cross a boundary; and

- Studies of anti-icing in British Columbia have indicated that although the number of crashes is reduced through anti-icing, the severity of the crashes that do occur has increased. In conversation between the author and the Insurance Corporation of British Columbia, there is speculation that this may be due to higher speeds on bare/wet pavement, more sports utility vehicles involved in crashes, or both.

It is clear that when properly used, the benefits that can be accrued from adopting an anti-icing strategy are enormous. However, as pointed out by agencies conducting anti-icing, perhaps the most important reason for anti-icing is the improved level of service and hence increased safety for the traveling public. Anti-icing permits an agency to provide the same level of service at a reduced cost, or an improved level of service at the same or reduced cost of current snow and ice control strategies.

RWIS COST SAVINGS

In the SHRP RWIS investigation a benefit-cost model was developed to show the potential return on the investment for RWIS in terms of a benefit/cost ratio [12]. Model inputs included the cost of RWIS hardware and weather forecasting services; the road network being maintained; and the labor, equipment, and material costs for snow and ice control. The model was run using variations in forecast accuracy above a baseline level of 50 percent accuracy. The model used an initial RWIS procurement in Washington State and the in-place system in the Denver, CO area as examples. Washington State DOT purchased five systems to test in the Seattle metropolitan area while the Colorado DOT had installed 14 systems at that time in the Denver area. The model results showed a B/C .of 5.0 for the Seattle area system and a 1.1 for the Denver system. The difference in the results was basically a function of the cost of the hardware purchased.

The benefit/cost model developed for the SHRP RWIS Project was developed to determine benefit-cost ratios for RWIS implementation. A large development effort would be required to upgrade and restructure the model to analyze anti-icing tactics. Also, unfortunately the original benefit-cost model software developer is no longer alive.

The Minnesota DOT (Mn/DOT) investigated the development of a statewide RWIS in the mid-1990s. Even though Mn/DOT initially planned a system of approximately 270 sites, Mn/DOT calculated that the savings in winter maintenance would amortize the fully loaded (included projected communications, maintenance, and training costs as well as hardware costs) system cost in six years. Over the next few years, the FHWA asked agencies to document cost savings from RWIS. Table 2 provides a list of RWIS cost savings documented in articles and FHWA Technical Briefs. All of the articles related to RWIS mentioned cost savings. Only those with actual cost savings are listed.

Table 2. RWIS Cost Savings

Agency	Publication Reference	Cost Savings
Maryland DOT	[13]	MD projects a $4.5M system will pay for itself in 5-7 years just with reduced standby time.
Massachusetts Highway Department	[14]	1. Saved $53K in first year with nine RWIS in Boston area; $21K in one storm alone. 2. Estimated savings of $150-$250K over a typical Boston winter.
Minnesota DOT	[15]	Estimates a 200-1300 percent return on the investment.
Nevada DOT	[16]	Projects a $7M savings over 25 years in the Lake Tahoe basin area due to reduce chemical usage, more efficient scheduling, and less damage to vegetation.
New Jersey DOT	[17]	Agency has cut snow and ice costs 10-20 percent or more.
North Dakota DOT	[18]	Saved $10K-$15K on one bridge in 4 storms with reduced sand usage.
Texas DOT	[19]	Savings in labor, equipment, and materials in the first two or three storms paid for the RWIS installations
West Virginia	[20]	1. Saved $2,300 per storm in labor. 2. Saved $6,500 of salt per storm. 3. Estimate $200K/yr savings for typical winter weather 4. Paid for the RWIS in one year.

COST SAVINGS FROM ANTI-ICING

As pointed out in the benefits of RWIS, one of its true values is its ability to allow an agency to transition with confidence to an anti-icing strategy. Anti-icing has its own associated cost savings. As with RWIS, numerous benefits are possible using anti-icing. Cost reduction is only

one of the benefits identified. Table 3 provides stated cost savings associated with anti-icing obtained from the FHWA Winter Maintenance Clearinghouse documents.
Costs for snow and ice control are typically reported through an agency's maintenance management system. Labor, equipment, and material costs are captured by a work code for snow and ice control. They are usually not broken down by strategy, such as anti-icing, deicing, or mechanical removal of snow or ice with or without traction enhancement. It is therefore rather difficult to capture costs savings when transitioning to a new practice. Most agencies contacted said they don't know how to document savings.

Table 3. Cost Savings Resulting from Anti-icing

Agency	Publication Reference	Cost Savings
Colorado DOT	[21]	Sand use has decreased 55 percent. All costs considered, winter operations now cost $2,500 per lane mile versus $5,200 previously.
Kansas DOT	[22]	Saved $12,700 in labor and materials at one location in the first eight responses using anm anti-icing strategy.
Oregon DOT	[23]	Reduced costs for snow and ice control from $96 per lane mile to $24 per lane mile in freezing rain events.
Washington DOT	[24]	Save $7,000 in labor and chemicals for three test locations.
ICBC (Insurance Corporation of British Columbia)	[25]	1. Accident claims reduced 8% on snow days in Kamloops, BC: estimated savings to ICBC $350,000-$750,000 in Kamloops 2. Potential annual savings of up to $6 million with reduced windshield damage.

In addition to the problem of documentation, annual variability can change bottom line numbers for the costs over a season. Annual costs essentially need to be compared to some weather index that accounts for the variability. There is probably a minimum fixed cost for snow and ice control and then savings accrue with the new practice above that minimum cost. When costs are reduced, an agency needs to determine how much is saved as a result of changes in practice or how much may have resulted from differences in weather from the norm.

If an agency starts out to document cost savings, keeping in mind some of the benefits described for anti-icing can help the agency zero in on cost savings. The North Central Region (NCR) of the Washington DOT has embarked on an expansive anti-icing program with liquid chemicals.

The NCR does not use solid chemicals to a large extent, so their anti-icing program is limited to pretreatment opportunities. With relatively reliable weather forecasts, they are able to identify those opportunities where they can use liquid chemicals and not get caught with wet pavements that transition to frozen pavements.

As the NCR transitioned to anti-icing, they made a concerted effort to try to document savings over the 1991-2000 winter. Table 4 provides documented savings identified by separate Area superintendents and shed supervisors for pretreatment anti-icing activities in the NCR. The information was obtained from an April 2000 post winter meeting held in Wenatchee, WA [8].

As is the case with much of the attempts to document savings, some of the savings described in Table 4 are more descriptions of benefits rather than savings. However, one interesting, almost anecdotal savings was discovered inadvertently. Washington Pass on the North Cascade Highway in the northern Cascade Mountains of Washington State is closed every winter due to the huge amount of snow that falls. It becomes impossible to remove the snow. A crew from the Twisp shed made an anti-icing pretreatment in early November as a winter storm approached. The storm ended up becoming the event that caused the pass to be closed due to snow accumulation. The crews went into the Pass in late March to begin the snow removal process to open the highway. After removing snow with snow blowers and getting down close to the pavement, the crew found that there was no bond between the snow cover and the pavement. The anti-icing in November had prevented the bond and the crew was able to achieve bare pavement in one hour after four months of snow cover.

The Iowa Department of Transportation shared the results of their first year of conducting anti-icing operations on all Interstate highways. Although for the most part the benefits mirror those identified in Table 4, the following additional, or perhaps differently worded benefits were identified [11].

- "Bridges stay wet"
- "Don't have to worry about bridges, more time to work and respond to occurrences."
- "Increases time to respond. Light storm may not have to respond."
- "100% success on frost."
- "… less cost in blades."

In all fairness, one Area out of 26 reporting indicated that they could not " … see benefits."

In addition to the benefits described, Iowa DOT also asked Area Supervisors for any comments they had received from internal (DOT employees) and external (public, customers) sources. There were both favorable and unfavorable comments provided. Table 5 provides a listing of comments obtained. Each of the rows represents comments from one Area. The verbiage was extracted nearly verbatim. The actual Areas are not identified in this table.

Table 4. Agency Savings from Anti-icing in the Washington State DOT's North Central Region during the 1999-2000 Winter [8].

Location	Savings
Wenatchee	Used 64% more liquid but 70% less sand compared to the 3-year average. $23,000 savings on the books.
Leavenworth	1. Blewett Pass shed: Reduced sand usage from 12,000 yd average to 4,000 yd. Also less accidents, less overtime. 2. Scenic shed: 5000 yd sand cut down to 2600 yd. 3. Stevens Pass shed: Less tort claims, less guardrail damage. 4. Leavenworth shed: Eliminated need to clean up sand; removed impact on salmon
Moses Lake	1. Moses Lake Area: Able to use contingency shifts with four 10-hr shifts. Eliminated weekend work and overtime and freed personnel to do other highway maintenance. Less facility damage repair. 2. Moses Lake and Othello sheds: Lowest cost per lane mile for snow and ice control in Eastern Washington. Accident rates way down.
Omak	1. Okanogan shed: Less sand used, accident rates way down. 2. Twisp shed: Cut sand usage by 1/3; reduced tort claims. 3. Electric City: Saved call out and overtime during weekends and the holidays.

Table 5. Comments on Anti-icing from Iowa DOT Employees and from Customers When Conducting Anti-icing Operations

Employees	Customers
… felt worked well	
Some employees felt it was a waste of time	[obscene gesture]
No	What were we doing
No	What were we spraying
Employees like	Keep up the good work. Schools, Mayors, Counties, Cities. TV has helped.
No	No
Crew was favorable	City and [highway patrol] road conditions improved greatly
	Curiosity – want to know how it works. City and countries want to know when to use it.
	Complaints on vehicles when anti-icing
Dirty vehicles (sate wide) Our intelligence?	Dirty vehicles (state wide) Daylight hrs – bad and people not knowing
Compliments, better level of service	Dirty vehicles, what are we doing
	Complaints way down this year. Lots of work to eliminated the heavy spray
See a benefit	Spray vehicles, don't understand what we are doing. Benefits – Clean up
	Spray vehicles, semi's $75 to wash. What are we doing
Doesn't work putting it down	Cars sprayed
	5 calls all winter
	120 phone calls in 1 day, day before treatment people did not understand
	"Coffee Shop" talk – explained what was going on, everything was ok
Service has improved, don't stop what you're doing	Liked what we're doing
Less windshield damage	Need to inform public better on when and why we anti-ice

CHAPTER 6
CONCLUSIONS/RECOMMENDATIONS

It can be readily seen from SHA comments provided in Chapter 3 and the listing of benefits and costs in Chapter 5 that the snow and ice control strategy of anti-icing can provide significant benefits. However, in order for anti-icing to be effective, decision makers also need good weather information. RWIS can provide that information. It can therefore be concluded in general, that anti-icing:

- Can be an effective strategy to improve the snow and ice control level of service;
- Can reduce costs of providing a specified level of service. Based on the surveys and interviews, savings of 10-20 percent of an agency's snow and ice control budget can be realized once fully implemented. Snow and ice control costs per lane mile can be reduced up to 50 percent;
- Can increase safety for the traveling public through reductions in accidents;
- Needs to be carefully executed based on existing and expected road and weather conditions;
- Can create hazardous driving conditions if executed incorrectly;
- May require a significant capital investment in order to fully implement;
- Requires reliable and accurate RWIS data and information;
- Requires appropriate training of personnel from operators to decision makers;
- Requires a good public information program so that the traveling public understands what the maintenance people are doing and the purpose and expected benefits of the strategy;
- Can minimize the environmental impact of snow and ice control for air, water, and the roadside environment; and
- To be successful requires an agency to develop a chemical priority policy for winter maintenance.

Based on the potential benefits of the anti-icing strategy, it is recommended that every agency responsible for snow and ice control consider the pros and cons of implementing anti-icing. As winter level of service expectations from the traveling public increase, the only way many agencies may be able to improve their level of services is with anti-icing.

Agencies conducting anti-icing or contemplating implementing the strategy should monitor the results of the in-progress snow and ice control research being conducted through the NCHRP project 6-13. Anti-icing is one of the strategies/tactics being evaluated under conditions not evaluated in the FHWA T&E 28.

It is also recommended that agencies consider developing performance measures for snow and ice control so that they can document the level of service provided and assess the need for implementing different strategies and/or tactics. These performance measures should consider both within-storm and end-of-storm level of service goals.

Agencies considering implementing anti-icing should contact agencies currently practicing anti-icing to determine how to get started. Consideration needs to be given to the equipment and

materials required, the budget process, environmental concerns, and dealing with the public and even own agency personnel. A successful anti-icing program needs the buy-in of all participants.

An obvious first need is to develop a sound anti-icing training program for operators and decision makers. The training should be performance based and should incorporated decision making scenarios. A part of this training should include detailed understanding of the "Manual of Practice for an Effective Anti-icing Program: A Guide for Highway Winter Maintenance Personnel" [7]. A copy of this document should reside in every highway maintenance facility conducting or about to conduct anti-icing.

It is also recommended that agencies adopt a benefit/cost methodology to formally document the costs and benefits of anti-icing. Such a methodology would aid in the assessment of the efficacy of implementing fully or just continuing with the practice of anti-icing.

Benefit/cost methodologies can compare the costs of various strategies to the costs of anti-icing. A reduction in cost when conducting anti-icing would be an obvious benefit. This requires keeping track of equipment, labor, and materials costs. Examples of benefits described were reduced overtime costs and reduced chemical costs. Agencies involved in applications of abrasives may not show a decrease in materials costs because they have changed from one form of material to another and the costs may be similar, however the results will differ. Costs associated with abrasive cleanup need to be included. It is also recommended that a weather index be used to identify the character of a particular season when comparing annual costs of snow and ice control to ensure the costs can be adequately compared and the benefits assessed.

Benefit/cost can also be determined from performance assessment. This can be based on level of service goals, such as the time to attain bare pavement when conducting anti-icing compared to the time it takes to attain bare pavement using other strategies. A control section can be used to determine the difference in costs between the strategies. It is also recommended that within-event goals be established in order to determine the benefit of anti-icing. This procedure can be a surrogate for determining the benefit/cost when looking at outcomes.

Outcome-based performance assessment involves evaluating the benefits related to anti-icing from, e.g., reduced accidents, decreased fatalities, improved mobility (vehicle counts or speeds), reduced facility and environmental damage, decreased structural corrosion, etc. It is recommended that goals be established and assessments be made of the improvements in these outcomes when conducting anti-icing. In some respects, the true benefits of anti-icing may be qualitatively estimated from the outcome-based performance assessment.

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