Performance Based Winter Maintenance Operations Decision Making

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ABSTRACT

Measuring performance for winter maintenance operations decision-making is a multi-disciplinary process. It involves both earth and atmospheric sciences, multifaceted application of physics and chemistry and effective communication of roadway and weather conditions into the motor vehicle operator's decision-making process. The global aspects of winter maintenance operations call for an integrated systems approach combining the skills of the meteorologists, operations personnel and motorists.

The first section of this paper will briefly outline the nexus of the basic research in the Strategic Highway Research Program, which provided the foundational approach for introducing advanced road weather information equipment and data into the winter maintenance operations process and document the successful implementation of the technology. It will also examine the education and training processes used to change a workforce culture from a reactive winter maintenance response to a proactive/systematic approach that has raised level of service, reduced cost and lessened the negative impact to the environment. Performance indicators will be illustrated and training investments quantified and explained.

The second section of the paper will discuss progress being made in field testing a maintenance decision support system which utilizes computer applications of treatment strategy algorithms to assist operation decision makers in optimizing treatment solutions. Rapid computer iterations assist the decision maker faced with quick developing or changing winter storms.

The third section of the paper will explore Intelligent Transportation System (ITS) application opportunities for informing motorists of current and forecasted road-weather conditions. Current usage will be documented as well as how the information will likely assist motorists within the next few years with their trip making decisions to improve both mobility and safety.

PERFORMANCE BASED WINTER MAINTENANCE OPERATIONS DECISION MAKING

Background

Safe, reliable, all weather, every season mobility continues to be the demand of the motoring public. Meeting these demands posses unique problems for winter maintenance operations personnel and the motoring public. Winter maintenance operations decision-making is a multi-disciplinary process. It involves both earth and atmospheric sciences for maintenance operations and effective communication of roadway and weather conditions into the motor vehicle operator decision-making process. The global aspects of winter maintenance operations call for an integrated systems approach combining the skills of the meteorologists, operations personnel and the motorist.

Foundational Research

Background

During the past decade, research has made great strides in providing new materials, methods and equipment for improving the winter maintenance and safety of transportation facilities. Topping the list of accomplishments is the way state and local governments are approaching snow and ice control operations. The state of the art has moved from reactive snow and ice control (initiating operations after the snow or ice begin to form) to a focus on proactive snow and ice control (beginning operations before the storm to prevent the bonding of ice or snow pack to the pavement).

Acquiring the Knowledge

The Strategic Highway Research Program (SHRP) began the process in 1988 with major investigative works on 1) Road Weather Information Systems (RWIS) and 2) Anti-icing (AI) operations (References 1 & 2). Due to the very short time span of the program (5 years) the major resources were directed to accomplishing the research and very little effort was spent on technology transfer and implementation. The feeling was that the state and local agencies would see the good in the research and simply adopt it.

An International Winter Technology Scanning Tour program followed the sunset of SHRP (Reference 3). This 1994 winter maintenance operations scan of Japan, Germany and Austria provided new knowledge about how other countries were utilizing RWIS, advanced material applications, and improved equipment design.

After completion of SHRP and the 1994 International Winter Scanning Tour, the Federal Highway Administration (FHWA) and the American Association of State Highway and Transportation Officials (AASHTO) realized that the states were not recognizing the value of this completed research. The major products of the snow and ice control research, Road Weather Information Systems (RWIS) and Anti-Icing (AI) were only being implemented in a few snow-belt states. A "Lead States" program was put in place to accelerate the implementation process. At the end of the Lead States program it was concluded that both RWIS and AI are complicated systems and require initial and refresher training to achieve understanding and maintain skills of the users. The Lead State Team determined this training could best be accomplished with the development of an interactive computer-based, stand-alone, training program.

Implementation with Education & Cultural Change

When the Lead States program was sunset, the responsibilities for developing and implementing the computer-based training program was handed off to the AASHTO Snow and Ice Cooperative Program (SICOP). The Aurora Consortium, an RWIS research consortium, had training as one of its top program priorities. The Aurora Consortium and AASHTO SICOP agreed to partner in the development of a national AI/RWIS training program with Aurora taking the lead in developing the scope of work and obtaining a contractor to build the computer-based training program. AASHTO was designated to be the lead agency in establishing a pooled fund program to provide the necessary financial support and technical guidance to develop an innovative national computer-based, AI/RWIS training program for state and local governments. SICOP was charged with rising the necessary funding and coordinating the project. The American Public Works Association (APWA), the National Association of County Engineers (NACE) and over 90% of the snow-belt states have contributed to the pooled fund program.

Two versions of the CBT program, one generic and the other customized are the end products of this pooled fund effort. Each version is a menu-driven, hyper-linked, interactive program manager. The student once logged in can work through this stand alone training from beginning to end, like a book, returning to the menu at intervals, as desired, to select another path. The content is photographs, illustrations, text, video, charts, animation, interaction, narration and other means of communications. . There are opportunities at various points to assess the progress the user is making educationally, including quizzes, scenario-based problem cases, and exercises. The training can be individually administered or used in a group setting and can be the foundation for a certification program.

The course consists of seven lessons containing a total of 38 units. The complexity of integrating the physical sciences associated with anti-icing field operations is illustrated in CBT content outline listed below:

Lesson I: Introduction to Anti-icing and Winter Maintenance
- Unit 1: The New World of Anti-icing
- Unit 2: Benefits of Anti-icing
- Unit 3: Anti-icing in a Nutshell
- Unit 4: Units of Measure

Lesson II: Winter Road Maintenance Management
- Unit 1: Components of a Successful Anti-icing Program
- Unit 2: Preparing for the Winter Season
- Unit 3: Level of Service
- Unit 4: Data Collection and Record-keeping

Unit 5: Anti-icing Communications and Legal Matters

Lesson III: Winter Roadway Hazards and Principles of Overcoming Them
- Unit 1: Water and its Winter States
- Unit 2: Road Surface Heat
- Unit 3: Condensation and Dew Point Temperatures
- Unit 4: Pavement Temperature—It's the Key!
- Unit 5: Snow, Ice and the Roadway
- Unit 6: Snow/Ice Bonds and Freezing-Point Depressants
- Unit 7: Dilution of Solution
- Unit 8: Chemical Concentrations and Application Rates
- Unit 9: Friction

Lesson IV: Weather Basics
- Unit 1: Weather and Winter Road Maintenance
- Unit 2: Air, Atmosphere, Heat and Humidity
- Unit 3: Weather Systems
- Unit 4: Regional Weather Influences
- Unit 5: Precipitation Hazards
- Unit 6: Non-Precipitation Hazards

Lesson V: Weather and Roadway Monitoring for Anti-icing Decisions
- Unit 1: Radar
- Unit 2: Weather Observation and Data Gathering
- Unit 3: An Introduction to Road Weather Information Systems
- Unit 4: The Importance of VAMS
- Unit 5: Eight Critical Questions
- Unit 6: Combining Anti-icing and the Traditional Approach

Lesson VI: Computer Access to Road Weather Information
- Unit 1: An Introduction to the RWIS Screens
- Unit 2: Navigating Through the System
- Unit 3: Other Online Resources

Lesson VII: Anti-icing Practice in Winter Maintenance Operations
- Unit 1: Preparing for the Season
- Unit 2: Equipment Types, Preparation and Maintenance
- Unit 3: Material Preparation and Storage
- Unit 4: Chemical Application Rates
- Unit 5: End-of-Season Tasks

The interactive CBT engages the student with the first screen:

- Splash screen appears each time the CBT is launched. It is a composite of small images reflecting training program content. As the images appear, music plays in the background. The splash screen requires about 15 seconds to build. If the student desires to bypass this screen, pressing the space bar or enter key will advance to the log-in screen.

- Log-in screen must be completed each time so student progress can be recorded. Log-in requires first name, last name, password, and job title. Thereafter the Microsoft® Agent "Jake", an online assistant, will address the student by their first name. Jake is an animated conversational personality that walks the student through the tutorial (discussed below) and provides assistance when the student needs help. In addition to the role of a guide, Jake will appear on occasion to drive home a point or sometimes to just entertain.
- Welcome video will present a brief video introduction to the course. The welcome video will play the first time the student uses the CBT.
- Tutorial will familiarize the student to the features and functions of the CBT. The full tutorial requires 31 minutes. The student can go through the entire tutorial or select tutorial topics. When the student logs back into the program for a subsequent session, they can revisit the entire tutorial, select topics or skip the entire tutorial.
- Road Map appears once the student exits the tutorial. The Road Map illustrates the student's progress and directs them to units within each lesson. Each road sign on the screen represents a lesson in the course. Lessons must be completed in order. Completed lesson signs will be checked off as soon as the student works through all of the lesson content and earns a passing score on the Post-assessment quiz and scenario.
- Lesson Introduction—each lesson begins with a video introduction to the content in that lesson. The main topics discussed in the forthcoming lesson are displayed on the screen as a real person host mentions them.
- Pre-assessment quiz is administered after the Lesson Introduction. The purpose of the Pre-assessment is to evaluate what the student knows before going through the lesson so it can be compared to what they know after going through the lesson. The quiz contains questions in a variety of common formats (multiple-choice, true/false, and fill-in-the-blank). On the last question of the Pre-assessment a "Check My Score" button will appear. Clicking on that button will display a score panel with student results.
- Lesson Content in each lesson is organized into units. Each unit is broken down into screens. Lessons contain anywhere from three to nine units. Each unit has as few as five, or up to 40-50, screens. The lesson content is presented using multimedia elements, including:
    - Text
    - Bullets (key points)
    - Photographs
    - Illustrations
    - Charts, graphs or tables
    - Screen element highlighting
    - Narration
    - Animation
    - Digital video
    - Sound effects
    - Mouse and/or keyboard-controlled interactive exercises and simulations
    - Review questions

  Interactive exercises will "engage" the student and topic being discussed. Review questions will be presented about every 5 to 10 screens. These are designed to check the students understanding of the topic being discussed on the past few screens. Review questions are presented in a variety of formats, such as multiple choice, fill-in-the-blank, true/false, or drag-and-drop. Feedback will be provided so the student can see how they did and if they missed a question, what the correct answer is.

- Knowledge Base is a warehouse of information related to AI/RWIS. The student should think of it as an online encyclopedia. Material in the Knowledge Base is arranged by tab group's discussion topics by subject or area or in an alphabetical index. In addition to text, Knowledge Base discussions may include photographs, diagrams, tables, web site links, digital videos, etc. Some discussions include links to other discussions. These are identified as blue underline text. The student can click on these "hot terms" to jump to those discussions in the Knowledge Base.
- Glossary contains a list of AI/RWIS terms and their definitions.
- Post-assessment quiz is to evaluate what the student knows after going through the lesson. On the last question of the Post-assessment a "Check My Score" button will appear. Clicking that button will bring results of the Post-assessment quiz and Pre-assessment scores so the student can compare what they now know after going through the lesson compared with what they knew beforehand.
- Scenario—while the Post-assessment quiz evaluated the student's knowledge of AI/RWIS facts, the scenario evaluates their understanding of the lesson content by asking them to put the knowledge they have gained into practice. It is well known that working with theories is one thing; working within the constraints of the real world can be quite different. The scenario room gives the student hands-on practice in a simulated winter maintenance facility so that they can develop and refine their winter maintenance decision-making skills. The scenario room is set up to look like a field maintenance garage office. It provides the student with the tools most maintenance facilities have in some form or other to learn of an impending winter weather event. They should be able to research the particular nature of the event and make operational decisions based on that research. Everything the student does in the Scenario Room is tracked and evaluated. The student is encouraged to strive to use all of the pertinent tools available, yet do not waste time clicking on objects that will not aid for the particular event. Detailed feedback will be provided once the student has made an operational decision. If the student does not pick the optimal solution to the problem, they will learn what the optimal solution is. The results of their decision will be compared with the results of the optimal solution. This way the student will learn the consequences of making a less-than-optimal operational decision. The feedback will also list each step taken, the order they took each step, and the time needed to complete the step. There are two scenario modes: Practice and Evaluation. Practice mode lets the student work through the scenario without being graded. A student can take up to three practice scenarios before tackling the Evaluation, or graded scenario.
- EPSS Mode—The AI/RWIS CBT continues to be a valuable tool even after the student completes the course. When the student finishes the CBT, a new feature is activated. This feature is known as the Electronic Performance Support System (EPSS) or EPSS Mode. The student can now access this feature through the Road Map icon on the Road Map screen. The EPSS Mode screen is divided into two main panels. The panel on the left includes a scrolling alphabetical list of discussion topics in the CBT. The student locates the topic they wish to review, highlight the topic by clicking on it and then clicks on the "Go to Selected Topic" button to jump to the first screen of that discussion. Above the alphabetical list of topics there is a Search field. Rather than scroll through the extensive list, the student can type the first few characters of the topic of interest and the list will automatically scroll to the

first topic matching the characters the student typed in. On the right hand side of the screen, topics are organized into a content tree. If the student needs help, click the Help button. Jake will appear and provide the assistance needed.

Two versions of the CBT program, one generic and the other customized, were distributed in Spring 2003. APWA and NACE selected the generic version while all but two states desired the customized versions. Some states promptly began the customization process, while others reviewed the generic content and found it satisfactory for immediate implementation. Those states delaying customization felt that they could do a more complete customization after their maintenance workers had a chance to become familiar with the program content and determine how well the generic material fit their particular snow and ice control operations and learning processes.

Each state DOT formed their customization team generally consisting of supervisors, equipment operators and training personnel. Customizations included tailoring to their methods, equipment, policies and procedures and chemicals used in their snow and ice control operations. Training managers working with the team selected lessons and/or portions of lessons they wanted presented to the various job classifications in their organization and set the thresholds for minimum passing test scores. Some states had photos of snow and ice control equipment to include in the customization; others had to obtain the photos during the winter of 2003-2004.

A metric version of the CBT has been prepared for use in the Canadian Provinces. Converting to metrics was more than just doing the mathematics. There was a maintenance field jargon and techniques needed for gaining field acceptance. Also maps and radar had to be extended northward to provide adequate coverage of the Canadian Provinces.

Performance and Payback

RWIS and Anti-icing

The National Cooperative Highway Research Program documented benefits and cost savings from RWIS and Anti-icing technologies in their March 2001 report (Reference 4). These benefits included safer travel, increased level of service, cost savings and environmental quality. State departments of transportation reported 200 to 1300% return on investment, reduced labor and materials costs. The Insurance Company of British Columbia estimated $350,000 to $750,000 in accident savings in one city and annual province savings of $6 million in windshield damage. These savings were achieved before the computer based training program was available so it is anticipated even greater savings are occurring today as both operators and supervisors have a better understanding of the chemistry and physics of snow and ice control and how to optimize their operations.

Computer Based Training

Unanimous feedback from the State DOT maintenance personnel and trainers has been the CBT exceeded their expectations. The CBT was easily installed on their computers and fit well into their training program. Some DOTs made the CBT part of their career ladder curriculum while others let progress be a self-directed process. The CBT will work well in either the group or individual training mode. The individual training mode is the most popular use. Being a stand-alone CBT program, operators can train during periods where field conditions or weather result in less productive environment. Field operators and supervisors found the CBT very engaging and challenging. Most found two hours at a session fits best into their daily work schedule and does not wear them out. Since the CBT is a stand-alone application on the garage computer, it is readily accessible. Depending on student experience and ability, time required to complete all seven lessons varies from 20 to 40 hours.

Feedback from DOTs is the CBT has improved the skills of both supervisors and operators thus increasing the efficiency and effectiveness of all snow and ice control operations. Pre-testing and post testing of each student on each lesson provides the student and a training administrator a record of how much learning has been accomplished, how much time is being invested and pin points areas of difficulty where addition emphasis needs to be placed. Cost of a customized CBT that reflects an individual state's policies, procedures, equipment, etc was $30,000. Considering the average state has over 1,000 field operators and supervisors, calculates to an average cost per student of less than $30 making the CBT a very economical training investment.

Model Based Tools to Support Decision Making

Background

The CBT lays the basic educational foundation for snow and ice control decision-makers to assess the various road weather elements leading to an operational storm treatment strategy. This multifaceted snow and ice control problem is constantly changing so an optimum treatment strategy is usually a moving target. Being iterative in natural, an optimal solution can best be achieved with the assistance of a computer-based decision support system.

System Development

The FHWA recognized the complexity of the problem and developed a prototype winter Maintenance Decision Support System (MDSS). The objective of the MDSS effort is to produce a prototype tool for decision support for winter road maintenance managers. The MDSS is based on diagnostic and prognostic weather research and road condition algorithms, which have been a follow on from the SHRP and subsequent Test and Evaluation (TE-28) project efforts. The components of the prototype MDSS were developed by the Cold Regions Research and Engineering Laboratory, National Center for Atmospheric Research, Massachusetts Institute of Technology, Lincoln Laboratory, National Severe Storms Laboratory, Environmental Technology Laboratory and the Forecast Systems Laboratory. A description of the prototype MDSS can be found in Reference 5.

The MDSS was tested in several states during the winters of 2001-2002 and 2002-2003. Neither winter produced a sufficient number or variety of storm events to thoroughly test the system. The project is in its final year (winter 2003-2004) of evaluating selected prototype components in an operational environment. A final meeting of the MDSS stakeholders will be held in July 2004 in Boulder, Colorado. At this meeting, the laboratories will be holding a workshop to provide a detailed engineering overview of the MDSS and exchange technical information with private companies interested in exploring the MDSS technology. It is anticipated CDs with all of the software and documentation associated with the winter 2003-2004 demonstration will be available during the fall of 2004.

The MDSS goal is to provide on a single platform a display on the state of the roadway, recommended courses of action, together with anticipated consequences of action or inaction. Treatment recommendations include: timing of initial and subsequent treatments; type of treatment (plowing, chemical, etc.); and chemical amounts. The MDSS also contains a "what-if" scenario treatment selector. This means that the user is able to modify the recommended treatment times, chemical types or application rates and view the results of their "user-defined" treatment plan. The principles and operational techniques found in the final version of the MDSS must be consistent with those being taught in the AASHTO AI/RWIS CBT. Since both programs were built on SHRP and TE-28 results, they are currently parallel. However, as field evaluations continue and more experience with existing and new chemicals is acquired, the rules of practice module in the MDSS program will likely be modified. As those modifications become accepted rules of practice, the content in the CBT will need some revision.

Performance

Testimonials from field personnel were that the overall concept of the MDSS makes sense and will improve their ability to optimize treatment strategies. Like the AI/RWIS CBT, MDSS is an interactive and engaging program for field personnel and they like that. Input data from RWIS stations wasn't always accurate which compounded the difficulty of measuring the performance of the MDSS. Field personnel all agreed that MDSS has tremendous promise and is worth the effort to continue to work with the laboratories to make the system better. It is anticipated that MDSS will be integrated into the product lines of private companies so that the technology can be used to raise the level of service of all snow-belt states.

Intelligent Transportation Systems Application

The Future Road Weather System

Significance progress in observational capabilities have been made by the National Weather Service and Departments of Transportation, making it possible to obtain a more comprehensive look at current weather and roadway conditions. Faster computers and more sophisticated modeling make resolving important phenomena on small space and short time scales possible. Departments of transportation have implemented dynamic message signs and highway advisory radio to communicate with drivers while en route. Automobile manufacturers are providing a wide variety of onboard computing and telecommunications tools in new vehicles. Cars and trucks are able to detect and respond to road and weather conditions with ease. Examples are windshield wipers that turn on with the presence of moisture on the windshield and ABS brake systems that alert the drive when there is a loss of traction. These "smart vehicles" with global position systems will eventually be able to stay in touch with weather information providers and traffic management centers and be informed of suboptimal conditions. Drivers will be able to use route-finding tools to determine optimum routes for navigating during weather or congestion events. Likewise traffic management centers will be able to monitor the “smart car” system for present road weather conditions.

CLOSING THOUGHTS

The author has visited Sapporo, Japan in 1994 and 2002 and Lulea, Sweden in 1998. While in Sapporo visited their traffic management center and national weather service to observe how the staffs of the weather service and the traffic management, both housed in the same facility and same room, collaborate to manage peak traffic during inclement weather. Many of the technologies listed in the Intelligent Transportation Systems Application section of this paper were being utilized in Japan in 2002. The E-18 corridor in Sweden and Finland is also utilizing these advanced ITS techniques. An April 2004 conversation the author had with a staff engineer of the Swedish National Road Administration revealed that these ITS technologies had a surprising positive affect on the driving habits during the winter of 2004.

These positive results in other countries hold hope that we in North America can also improve the safety and mobility on our streets and highways. A blueprint outlining a research agenda for improving road weather services published in April 2004 by The National Academies will assist in guiding the process (Reference 6).

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