8.7 USE OF A MAINTENANCE DECISION SUPPORT SYSTEM TO DEFINE WINTER SEVERITY INDICES

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1. INTRODUCTION

The Pooled Fund Study (PFS) Maintenance Decision Support System (MDSS) is a toolset that provides support to roadway maintenance personnel in times of adverse weather conditions (Mewes et al, 2005). MDSS attempts to provide the best treatment options possible for maintaining the road surface while adhering to agency constraints. The goal of the PFS has been to provide guidance to achieve a more effective use of maintenance resources, and to improve an agency's effectiveness in maintaining an adequate level of surface on their roadways. Thus far the PFS MDSS has been used primarily as a short term prognostic tool used for looking at future road conditions as well as for a short term diagnostic look back at conditions over the preceding 24 hours.

This project is an extension of MDSS by making it a long term diagnostic tool. It attempts to make use of archived weather data in combination with the PFS MDSS road pavement model to simulate the required winter road maintenance activities over entire winter seasons. These simulated maintenance activities can then be used to accomplish several tasks:

- Justify the annual variance in winter maintenance costs.
- Provide post-season play back and evaluation of the effectiveness of current maintenance practices.
- Identify the economic and environmental impact of alternative approaches to winter maintenance.

The ultimate goal of the first task is to come up with a winter severity index that is based not on the winter's weather but rather on the modeled maintenance response required to adequately maintain roadways in response to the winter's weather. Since this type of index is generated objectively by the PFS MDSS road pavement model it should provide road maintenance personnel with the normalization required to compare and contrast agency operations in different winters.

2. BACKGROUND

Many different winter severity indices have been developed for transportation using a variety of different approaches. Strong, Shvetsov and Sharp (2005) have detailed several of these indices, including those of Hulme (1982), the Strategic Highway Research Program (1993), and Haider (2004).

The Hulme index was developed for use in England and uses the mean daily temperature for the winter, the number of days with snow lying at 9Z, and the number of nights with ground frost.

The Strategic Highway Research Program index is based on the efficiency of snow and ice control, and the weather. This index was developed because other indices where thought to be inadequate for maintenance purposes. This index again uses several meteorological parameters to come up with a winter severity index. When the index is shown spatially for each test station in the United States it was shown that the index was higher in the northern latitudes then in the southern latitudes. This index and population density was then used in a regression equation to determine a cost of the maintenance actions.

The Haider index is being developed by the Minnesota Department of Transportation. This index uses the number of snow events, number of freezing rain events, snow amount, and total storm duration.

Winter severity indices are also discussed in Thornes (1993) and Cornford and Thornes (1995). Another approach using artificial neural networks was discussed in Carmichael, Temeyer, and Bryden (2004) for the state of Iowa.

The aforementioned indices are generally based upon statistical relationships of meteorological variables to maintenance resources utilized. The approach taken herein differs these previous approaches in that instead of using statistical means to relate meteorological parameters to maintenance resource utilization, this project is using a road pavement model to diagnose the road condition and assess the maintenance activities and resources required to address adverse road conditions as per agency policies.

3. DATA AND METHODOLOGY

3.1. WEATHER DATA

Three different types of weather data were used in this project: historical National Weather Service (NWS) hourly METAR observations from the National Climatic Data Center (NCDC), National Centers for Environmental Prediction (NCEP) gridded North American Regional Reanalysis (NARR) data provided by NOAA/OAR/ESRL, and blowing snow data that is derived by applying the Functional Prototype (FP) MDSS blowing snow algorithm using data from the two preceding sources. Each NWS METAR observation was then lined up with the gridded NARR data sets to create a weather database from which the road pavement model could access information about hourly weather conditions on each test road segment throughout winter seasons.

Preprocessing of the NWS METAR observation dataset was required to resolve several problems in order to make the data useable. These problems included:

- Data holes
- Metadata problems
- Precipitation (including snowfall) rates were needed by not directly available
- Data quality errors

The data holes were particularly a big problem since there were a limited number of METAR observations next to the test road segments in question. These holes were filled using linear interpolation from data at the same site if the missing time span was less than 6 hours. Data holes that were larger then 6 hour were either filled in with the next closest station or disregarded. Thus, logic was created so that the pavement model would then stop execution at these data holes that were unfilled and start again after the hole. The surface METAR data also contained some missing error flags and blank values in the data. Left unprocessed these types of values would cause the road pavement model to become unstable. As such these values were caught and substituted with reasonable values.

The metadata that was downloaded with these files suffered from the problem that the latitudes and longitudes for a number of stations appeared to be off by a few tenths of a degree, and that the time zone information was not included for some stations. The latitude and longitudes were a particular problem for some road segments since some stations were being used to fill in weather data when they were in fact further away then other stations. This problem was fixed by comparing the current locations with a different set of metadata.

Since the METAR data do not contain reliable wintertime precipitation rates this information must be estimated. A qualitative algorithm already in use within the PFS MDSS system that estimates precipitation rates using the METAR present weather indicator, visibility and wind speeds was used to estimate the hourly accumulations of precipitation in the form of liquid, ice, and snow.

Operation of the pavement model also requires radiation information not available in the METAR dataset. As such these values were instead drawn from the North American Regional Reanalysis data. This data came with a temporal scale of three hours and a grid spacing of approximately 32 km. Because of the temporal scale the long wave radiation and percentage cloud cover values were linearly interpolated to hourly values. The short wave radiation was also interpolated to hourly but not using a linear relationship. For short wave radiation the station location along with the time of year was used to get a better interpolation between each three hour observation.

The final input weather dataset required to perform the seasonal simulations required for this work was blowing snow information. Due to its conduciveness to application with the other available weather datasets, the blowing snow algorithm from the FP MDSS was then used to generate an hourly index of blowing snow potential corresponding with the METAR and NARR observations. This algorithm takes into account snow age, maximum temperature, occurrence of liquid precipitation, and the wind speed over the interval of interest. More information on this algorithm can be found on the Nation Center for Atmospheric Research (NCAR) MDSS Functional

Processes Modeled by *HiCAPS*	
• Evaporation (mass / energy balanced)	• Condensation (mass / energy balanced)
• Sublimation (mass / energy balanced)	• Frost Formation (mass / energy balanced)
• Conduction of heat from precipitation	• Internal heat conduction within pavement
• Traffic splatter, splash, spray, compaction	• Snow / ice removal by plow
• Natural phase changes	• Chemically induced phase changes
• Heat exchange between air and pavement	• Emission of infrared radiation by pavement
• Absorption of solar and infrared radiation	• Time-varying pavement reflectance
• Insulating effects of snow & ice buildup	• Condition-dependent snow adherence
• Variable freeze points	• Water and chemical runoff
• Chemical dilution	• Chemical removal by traffic
• Residual chemical amounts and effects	
Other Features of *HiCAPS*	
• Explicit calculation of liquid, ice, frost, and snow depths on the road, allowing for mixed conditions such as slush	
• Support for modeling the effects of freeze-point depressing chemicals	
• Highly configurable pavement and maintenance equipment specifications	
• Coupled mass and energy balance	
• Support for modeling the effects of reported and proposed maintenance actions	

Table 1: Table describing the processes modeled by HiCAPS and some other important features of HiCAPS.

Specification Template and Procurement Guidance (2006).

3.2. MDSS SIMULATION SYSTEM

The pavement model that is used in the PFS MDSS is called HiCAPS. This model has been privately developed at Meridian Environmental Technology. HiCAPS uses an unsteady heat flow equation in combination with sophisticated parameterizations for representing heat and moisture between the road, atmosphere, and pavement substrate. This model also has a coupling between mass and energy balances. Thus, moisture deposited onto the road transfers energy to and from the road. The road must then have an adequate amount of energy to support evaporation or sublimation from moisture on the road surface. Table 1 shows the processes that are modeled by the HiCAPS pavement model.

The HiCAPS model serves as the core of the PFS MDSS simulation system. The PFS MDSS simulation system requires setting of several different types of configuration parameters before a seasonal run can be carried out. Some particular configurations that are needed include:

- Level of Service (road condition) settings
- Operating and Resource Constraints
- Standard or “Best” Practices

The Level of Service (road condition) setting is a set of configurations that tell the PFS MDSS simulation system what constitutes an acceptable road condition both during and after an event, and how long a period agency personnel are provided in order to regain a nominal ‘bare road’ condition.

Operating and resource constraint configurations are also set up in a similar fashion. This includes information on the chemicals and abrasives available for application, the range of application rates reasonable for the material on the specified route, the cost of those materials, local operating hours, and various other parameters that control the logic MDSS utilizes in making recommendations.

The need for the third type of configuration information would depend upon the nature in

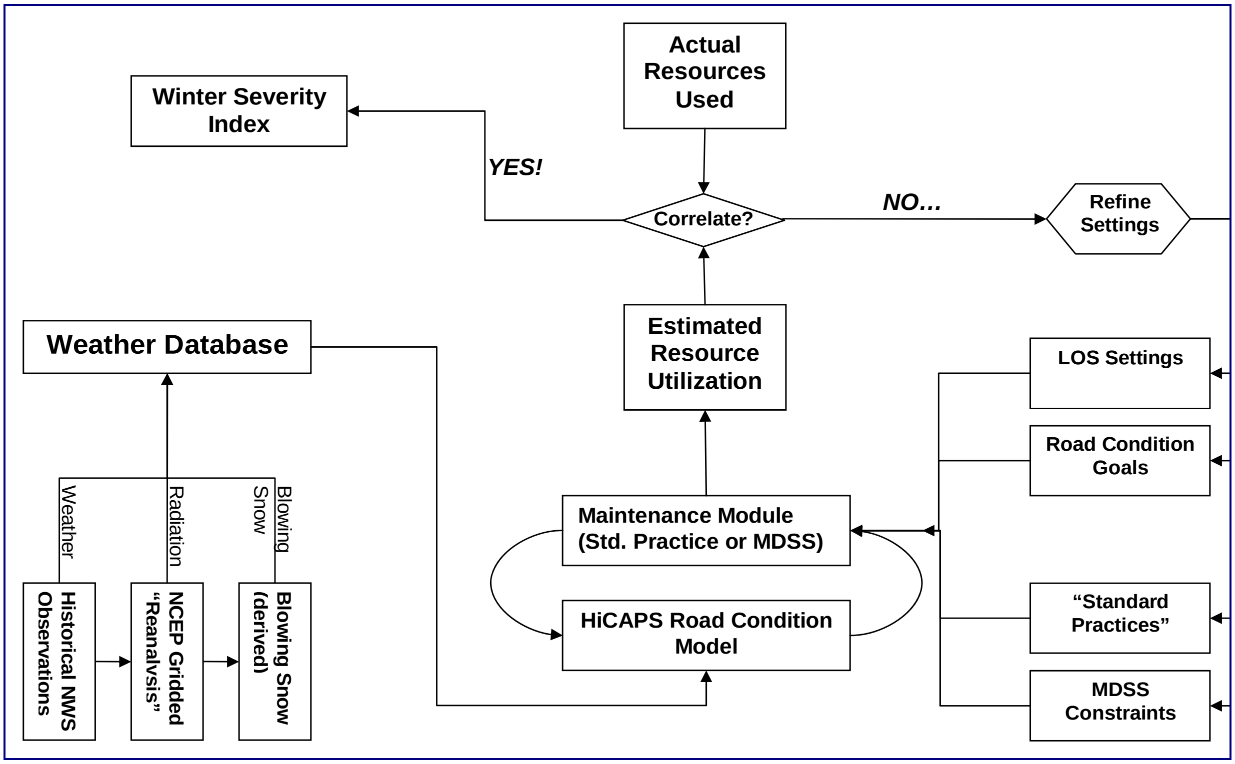

Figure 1: Flow chart showing the methodology of this project.

which an agency wished to implement the resulting Winter Severity Index. If the desire of the agency is to gauge the level of maintenance response relative to those suggested by published policies the system could be configured to prescribe maintenance responses taken directly from agency guideline documents. On the other hand, if the agency wished to have an independent measure of the severity of the winter that is not impacted by agency policies and/or practices then the system may be freed to prescribe the maintenance actions it deems appropriate for each individual situation. Both applications have considerable merit, but potentially different uses and outcomes.

Using these configurations and the aforementioned weather data, the PFS MDSS simulation system can be run over extended periods of time. In doing so the system creates a time series of maintenance activities that it has identified as being appropriate to address the adverse road conditions that develop on the road surface as a result of winter weather conditions. This information can be aggregated over time and across numerous maintenance routes to arrive at an estimate of required resource utilization for each season.

A key aspect of this simulation process is the refinement in the configuration settings provided to the system. Winter maintenance approaches vary widely both across states as well as within state agencies. The configuration settings provided to the PFS MDSS simulation system can easily over- or under-shoot actual maintenance activities (in terms of both resources utilized and road conditions achieved). As a result it is necessary to use historical agency records in order to fine tune these configuration parameters. Toward this end, several states in the PFS MDSS study have provided actual resource usage data with a temporal scale from hours to weeks. This data will be compared to the output from the PFS MDSS simulation system and used to refine PFS MDSS configuration parameters where configuration-related discrepancies are identified to exist. This whole process is illustrated in the flow chart given in Fig. 1.

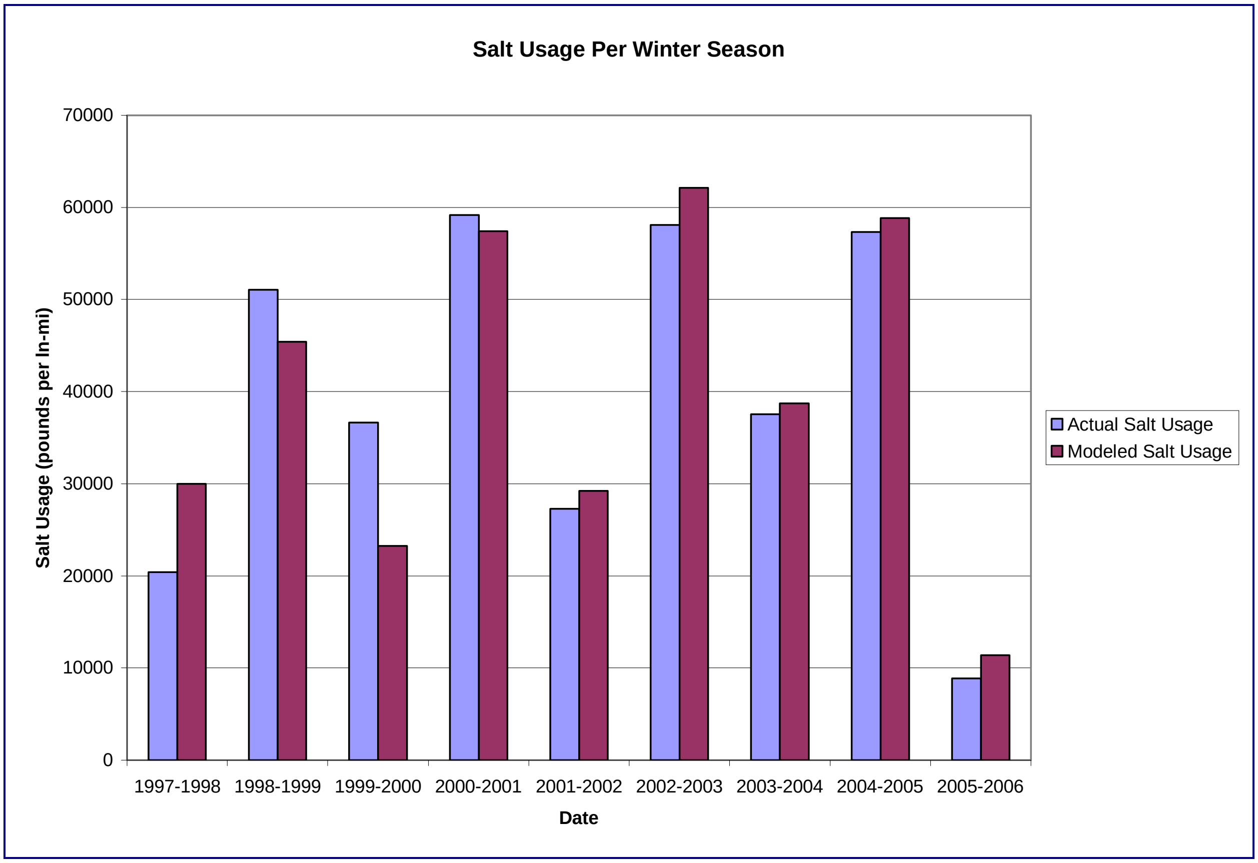

Figure 2: Plot showing the actual and simulated salt usage using the PFS MDSS on a New Hampshire winter maintenance route over the course of 9 winter seasons.

4. INITIAL RESULTS

At this early juncture in the research only one multi-season simulation for one maintenance route has been completed and compared with historical agency records. This particular route is located on I-93 in southeast New Hampshire. The graph in Fig. 2 shows the amount of salt the PFS MDSS projected should have been used following local standard operating practices vs. the actual amount of salt usage on the route as reported by the New Hampshire Department of Transportation. Surprisingly good agreement with reality was achieved with relatively little reconfiguration effort on this route. However, factors such as blowing snow and a less-consistent maintenance approach in other areas of the country will likely present substantially different and more difficult situations elsewhere.

5. FUTURE DIRECTIONS

Once a high degree of correlation between the simulated and actual maintenance data is found the system can then be used to develop a winter severity index. This process will involve significant scale-up issues and will also require consideration of how to aggregate the massive amount of resulting information into a simpler index or indices. The research has not yet reached this phase, so no results are available as of yet.

If the system is found to be successful some future work would include:

- Client program for viewing
- Better data ingest system

A client side program is already being developed to make viewing this data easier. The other refinement would be to improve the surface data using more sophisticated techniques for filling holes and perhaps developing a system to capture and ingest current data as it folds so that there is no reliance on static data archives.

6. ACKNOWLEDGMENTS

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