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THE POOLED FUND STUDY MAINTENANCE DECISION SUPPORT SYSTEM: A FUNCTIONAL OVERVIEW

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1. INTRODUCTION

Version 1.0 of the Pooled Fund Study (PFS) Maintenance Decision Support System (MDSS) was released to the participating states during the fall of 2004. The PFS MDSS is the first public / private venture into operational application of winter maintenance decision support technologies following the Federal Highway Administration's (FHWA) MDSS Functional Prototype demonstration. The PFS MDSS integrates in-situ, remotely-sensed, and forecast weather information with data gathered from Road Weather Information Systems (RWIS), road condition reporting systems, and winter road maintenance activities data collection platforms to provide maintenance personnel with a suite of decision support tools.

2. MDSS DESIGN

The PFS MDSS approach focuses upon simulation of the 'contaminant layer' atop the pavement. Analyses of past weather conditions (including precipitation and radiation budgets) are integrated with RWIS observations as well as road condition and maintenance activities reports to provide an ongoing assessment of the past and present states of the roadway. The information integration occurs within the HiCAPS[TM,1] pavement model and supporting MDSS libraries. HiCAPS[TM] is a mass and energy balance pavement model that simulates the evolution of the roadway and its contaminant layer by modeling the combined effects of the individual fluxes and processes active on that layer. Sensible and latent heat fluxes are modeled using bulk formulations, while ground heat flux is modeled using the unsteady heat flow equation. The HiCAPS[TM] latent heat flux module accounts for energy and mass exchanges due to precipitation, evaporation, sublimation, condensation, deposition, conduction, and phase changes. A new chemical solution module was developed to support the need for modeling the effects of freeze point depressants on the state of the roadway.

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The ongoing assessment of the initial state of the contaminant layer discussed in the preceding paragraph is used in concert with weather forecast and available maintenance resources information to construct an initial/boundary value problem. Standard minimization techniques are used to find candidate maintenance actions that will maintain the required level of service in the most economical manner given available human, equipment, and material resources. Resources and service level information is preconfigured for each maintenance route, but can be adjusted by the user as resource availability and practical maintenance limitations change during a storm situation. The system also supports contaminant layer simulation for user-defined maintenance actions in a 'what-if?' virtual scenario mode.

The PFS MDSS supports application of the most commonly used freeze point depressant materials. In the simulation process a configurable amount of the applied material is assumed lost immediately upon application. For simulated plowing operations, the system estimates the depth of snow and ice remaining behind the plow based upon plow type and the road surface roughness. Immediate material loss during the application process is configurable and dependent upon the form of the material (e.g., dry, prewet, or brine). The depth of materials remaining behind the plow is configurable based upon plow type. Previously applied soluble / insoluble chemicals and grit are removed at the same fractional rate as the liquid / total moisture mass in the contaminant layer. Due to density considerations, liquid is assumed to preferentially reside near the bottom of the contaminant layer and is therefore generally removed at a lesser rate than frozen materials within the mixture. Moisture and maintenance materials are also removed by runoff, and by the effects of traffic.

Due to the lack of reliable and consistent research data on the cumulative effects of hundreds or thousands of vehicles upon the contaminant layer, the PFS MDSS instead models the effects of traffic on a more tractable vehicle by vehicle basis. Based upon average daily auto and truck traffic counts, the MDSS distributes vehicles across the contaminant layer at a rate that varies according to a configurable pattern throughout the day. Each vehicle is assigned a random lane, track

[1] HiCAPS is a trademark of Meridian Environmental Technology, Inc.

and vehicle width, and moisture within the tire tracks is splattered, sprayed, spread, or compacted depending upon the composition of the contaminant layer. Moisture and materials are moved laterally atop the roadway, and are also removed from the roadway depending upon the splatter, spray, and spread widths relative to the distance of the tire track locations from the edge of the roadway.

Decision support in the PFS MDSS is provided on a maintenance route, segment, and / or tile basis. A maintenance route is made up of one or more discrete segments of highway that are to be treated contiguously by a given maintenance vehicle. Each segment within a maintenance route possesses unique weather, construction, traffic, and environmental information. Maintenance needs within a single route can therefore vary considerably. However, the MDSS will only present maintenance action recommendations on the different segments of a given route that can be practiced with a single vehicle configuration and that can be performed at contiguous times with traversal, cycle, and dead times that are physically realistic. Note that although the materials recommended will be the same on all segments of a route, the recommended rates can vary substantially between segments based upon the modeled needs. Roadway information in the MDSS is generally displayed on a segment by segment basis. The smallest road subunit in the MDSS is the tile. A tile possesses no specific location within a segment, but is intended for modeling generalized variations in conditions along a segment (such as a sheltered area verses an open area). At this juncture information that is available at the tile level is hidden from the user.

Data is generally exchanged using simple and self describing text file formats. A central library has been developed for all IO function of the MDSS. Data is therefore accessed and written to the system using simple library calls. Most data is stored on a segment or tile basis. The GUI exchanges information with the server via http requests and uses a pull technology based off of an updating lookup file to keep data flowing to the client's computer, thus eliminating download delays. On the server side a process watches for incoming data from the meteorological service provider(s), compresses it, and updates this lookup file on an ongoing basis.

The PFS MDSS graphical user interface (GUI) is written in Java™[2] and distributed to the participating states as self-contained compiled executable. It has been constructed to meet the stringent criteria of state information technology divisions, including the ability to run the graphical user interface at remote locations from a central server. The functionality of the graphical user interface will be discussed in more detail in the following section.

3. USER INTERFACES

The primary mode of user interaction with the MDSS is through a GUI that is installed either on the client computer or on a central state server. Alternatively, the PFS MDSS also supports use of computer telephony technologies for both data gathering and information distribution.

The GUI design is based upon a 3-panel layout. The upper-left panel is a called the "Alert Panel". The lower-left panel is called the "Support Panel". The third "Primary Panel" of the display carries most of the functionality of the MDSS and takes up the right 2/3 of the GUI. In order to function well in all environments the PFS MDSS GUI has been designed to work at 600x800 screen resolution, but can easily be maximized to take advantage of additional screen dimensions when available.

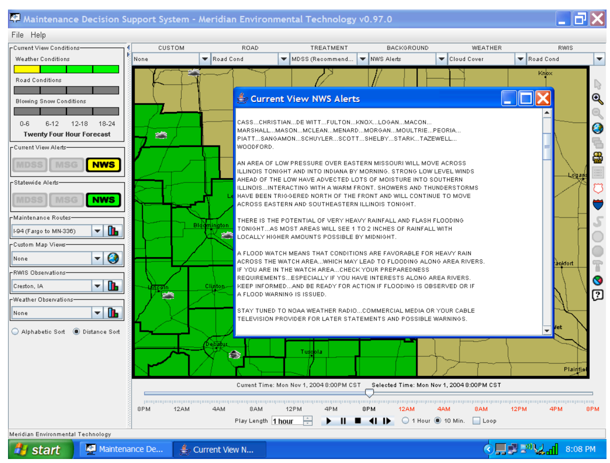

Figure 1: The Alert Panel of the GUI monitors for weather, road, and blowing snow alerts from the meteorological service provider and / or the National Weather Service.

The Alert Panel is present at all times, and conveys information about weather, road, and blowing snow conditions meeting specified alert criteria (see Figure 1). This panel of the FHWA's Functional Prototype was well received by test users, and is thus included in a similar fashion in the PFS MDSS. The alerts for the various conditions are presented using time-series based color bars, where the period in time over which the alert is valid is color coded based upon the perceived severity of the alert. Alerts for road conditions and blowing snow are intended to be provided by the state's meteorological services provider, while the weather conditions alerts are intended to come from both the

[2] Java is a trademark of Sun Microsystems, Inc.

meteorological service provider and the National Weather Service (NWS). A set of buttons within the alert panel allows the user to retrieve text messages associated with alerts issued by either the meteorological service provider or the NWS. Separate buttons hold information for the user's specific state, while a parallel set of buttons hold information for the user's specific 'view' (as defined by the GIS panel of the GUI, see Figure 2). Standard GIS formats are used for conveying alert information to the MDSS GUI so that the alert notices can be coupled with the user's GIS view even as the user pans into new areas.

The Primary Panel of the GUI holds most of the functionality of the PFS MDSS from the user's perspective. The Primary Panel can host one of four different "views". These views are the "Route View", the "GIS View", the "RWIS" view, and the "Weather View". The user selects which view is active in the Primary Panel using selection tools in the Support Panel. Alternatively, when in the GIS View the user can quickly switch to any of the other three views by simply clicking on objects located on the map display of the GIS View.

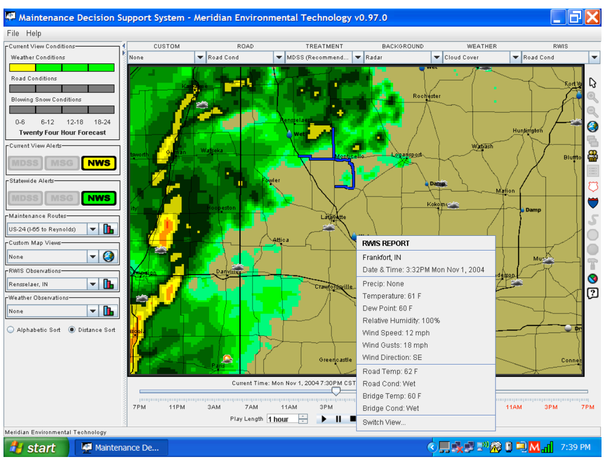

Figure 2: The "GIS View" of the PFS MDSS GUI shown in the Primary Panel. In this particular example an RWIS station on the GIS display is being probed for more detailed information.

The Geographical Information Systems (GIS) View is the geospatial display component of the GUI (see Figure 2). It is based upon the OpenMap™[3] open source Java GIS toolset. Users are provided a basemap with pan, zoom, and static GIS overlay capabilities (e.g., counties, cities, roads, etc.). These static overlays are distributed in the delivered executable and therefore are immediately available and responsive to user requests. In addition, the GUI presently supports four other dynamic overlay types: Road, Background, RWIS, and Weather. These overlays are dynamic in the sense that they change over time. The user is provided a time slider that can be move forward or backward in time to view past, present, or future data in a geospatial format.

The Road overlays are displayed in the form of selectable and color coded segments in the GIS View. They convey information about the MDSS' analyzed and forecast state for each road. Since the forecast state is dependent upon maintenance actions that have yet to be determined, the user is provided the option to visualize outcomes with "No Treatment", their "Standard Treatment", or the "MDSS Recommended Treatment". The Background overlays are comprised primarily of raster graphics (e.g., radar, satellite, etc.). The RWIS overlays are presented as point data (text or icons) at the locations of the various RWIS sites and convey information about road and / or weather observations. The Weather overlays are presented in a similar fashion, but display data observed by ASOS and AWOS sites instead.

Features displayed by the Road, RWIS, and Weather overlays in the GIS View are selectable with a single mouse click. This selection brings up an information box giving summary information about the selected item (see Figure 2). Within this information box there is an option to "Switch View…" by which the user can swap the Road, RWIS, or Weather Views into the Primary Panel of the GUI. As mentioned previously, the user can also switch the contents of the Primary Panel using selection tools that are always present in the Support Panel. It is therefore not necessary for the user to return to the GIS panel in order to switch between locations for a particular type of data or even to switch between types of data.

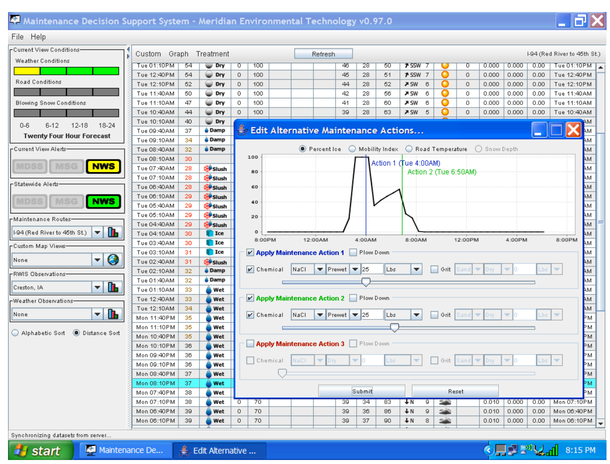

Figure 3: The PFS MDSS "Road View" displays time series of maintenance, road, and weather information to the user. A 'what-if' interface allows the user to view the expected results from candidate maintenance actions in a virtual setting.

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3 OpenMap is a trademark of BBN Technologies.

The Road View is intended to be the most powerful feature of the GUI once fully developed. The Road View presents a time series based portrayal of maintenance, weather, and road information for each maintenance route and segment (see Figure 3). These time series span from the past into the future, showing what has already occurred as well as what is expected to occur in the future. Since the state of the roadway and the maintenance actions that effect that state are dependent upon the treatment strategy taken, the user is allowed to compare expected results given no maintenance actions, the MDSS recommended maintenance actions, their standard maintenance actions, or an alternative 'what-if?' action specified by the user. The methodology behind the MDSS guidance recommendations was discussed in the preceding section. The specifics of the 'what-if?' actions are edited by the user via a simple interface. This functionality is intended to allow the user to attempt virtual maintenance actions and gain an understanding of the expected outcomes without the risk of carrying those actions out in reality. Information in the Road View is presented via either tables or graphs. The table format permits drag-and-drop reordering of information, as well as dynamic column resizing. Graphs of multiple parameters can be toggled on or off as well, and variables of similar natures can be overlaid on the same graph.

The RWIS and Weather Views function in substantially similar manners. They present the user with a time series view of RWIS, ASOS, and / or AWOS observations over the past 24 hours. The table and graph display formats used in the Road View are also utilized in the RWIS and Weather Views (see Figure 4).

In addition to the aforementioned GUI, the PFS MDSS is also relying upon computer telephony technology in order to move information into and out of the maintenance vehicles. A simple menu is provided through which a user can 'configure' a truck by selecting a material, rate, and plow position to be assumed for future maintenance activity reports. Thereafter the user is asked to call into the system each time the maintenance route is treated in order to report the maintenance action to the MDSS processing system (after which it can be incorporated into the ongoing assessment of the road states). The menu system can be circumvented entirely once the user knows its layout, permitting speed dial programming of cellular phones for reporting maintenance activities. The menu system also permits the driver to submit road condition and weather reports which are subsequently assimilated into the MDSS system. Through a final option in the telephony system's menu the user can choose to hear the latest projections of weather and road conditions on a given route in light of reported maintenance actions.

Note that although the PFS MDSS supports maintenance activities reports using computer telephony, this is not perceived as a viable long term mechanism for maintenance activities tracking. The need for automated maintenance data collection is widely recognized in the PFS member states. Most have platforms to collect and distribute this information available on only a select few maintenance routes. Where available the PFS MDSS will incorporate these reports in real time, with the hope of learning valuable lessons for future statewide deployments of such systems.

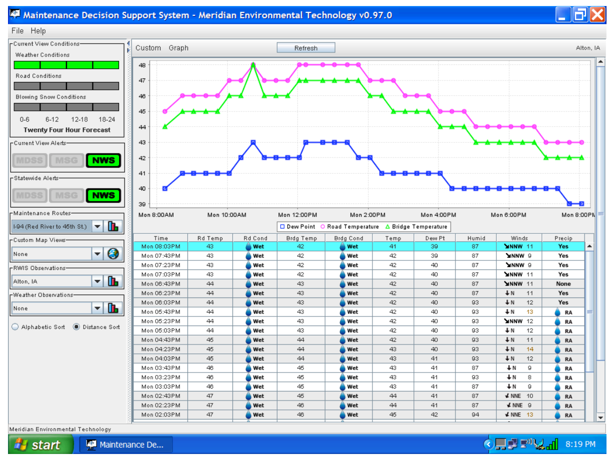

Figure 4: The "RWIS View" allows the user to view a history of RWIS observations at any site on-demand.

3. FUTURE ENHANCEMENTS

The PFS MDSS will enter its first winter demonstration test beginning in December of 2004. A comprehensive validation plan is being developed, and instrumentation to assess MDSS performance is being installed in the participating states. Based upon the results and user feedback collected during the demonstration test, the PFS MDSS will be modified and expanded to better meet user's needs in the future.