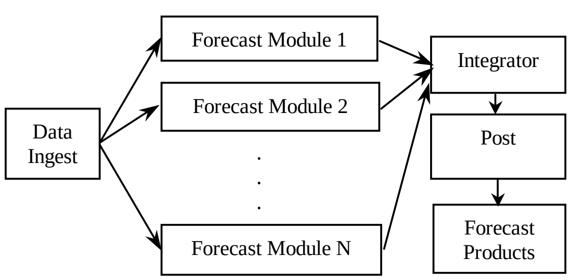
3.5 **AN AUTOMATED ROAD WEATHER PREDICTION SYSTEM FOR ROAD MAINTENANCE DECISION SUPPORT**

Bill Myers*, Melissa Petty, Jim Cowie
NCAR, Boulder, CO

A road maintenance manager faces a complex problem in determining if and when to allocate costly resources to counter winter roadway hazards. An advanced decision support system (DSS), much like those appearing in the aviation system over the last decade, is envisioned as an aid in this difficult task. Weather, road temperature, and mobility (slipperiness) forecasts are all critical components of such a DSS. In particular, weather is usually the trigger responsible for creating the other problems. An effective weather forecast is critical to the success of the DSS.

The development of a prototype Maintenance DSS (MDSS) is being funded by the Federal Highway Administration in partnership with the State Departments of Transportation. A component of this prototype system is an automated weather forecast system. The output of this weather forecast system must be tuned to the needs of the winter road maintenance community and interface with other components of the DSS. Its goal is to provide timely and accurate forecasts that are both temporally and spatially specific. To accomplish this the Road Weather Forecast System (RWFS) makes point forecasts out to 60 hours at locations along the highway ribbons. These forecasts are automatically updated every three hours.

The RWFS has been designed to be open with a highly modular architecture. The system develops a consensus forecast by combining a number of "independent" forecasts. Each of these forecast modules applies a particular forecasting technique to a data source. As new forecasting techniques are developed or as new meteorological data become available, it is relatively easy to plug a new forecast module into the system. Currently most of the data used are standard available NCEP products. However this is not a limitation and there is no reason other numerical weather prediction models or observational networks' data could not be incorporated.



Basic System Diagram

*Corresponding author address: Bill Myers, National Center for Atmospheric Research, PO Box 3000, Boulder, CO 80307; email: myers@ucar.edu

The RWFS has two groups of forecast sites. The first are termed "core" forecast sites. These are sites where observations are available. While not required, it is preferable that these observations be regularly disseminated in real-time, i.e. within a few hours of the observation time. The observations at these core sites are used to tune the forecasts to achieve a higher skill level.

The second group of forecast sites consists of non-observational sites. In the RWFS, these sites are located along the highways usually at 5-10 mile intervals, or at spots of interest such as bridges or locations near bodies of water. Currently, forecasts at these non-core forecast sites are generated from the higher quality core sites' forecasts by a climate-deviation interpolation method. As with all interpolation methodologies, the density of surrounding core sites affects the quality of the interpolated forecasts. For this reason, it is important to include as many high quality observational networks as possible.

The system produces forecasts for many standard meteorological variables verifiable by METARs or road weather sensors. Amongst these are the instantaneous variables like temperature, dew point, wind speed and direction, cloud cover, and visibility. There are a number of variables describing activity over a time period like three-hour and six-hour POP, probability of thunder, probability of fog, conditional precipitation types, and quantitative precipitation forecasts. Daily variables like maximum and minimum temperatures and 24-hour POP are also produced.

Broadly speaking, the system uses three major classes of forecast techniques. The first class consists of semi-static forecast techniques such as climatology and persistence. The second class consists of NWS MOS forecast modules. These forecasts are generated by pass-through of MOS forecasts at the MOS sites, and "smartly" interpolated MOS forecasts elsewhere. The third class of forecast modules use a Dynamic MOS (DMOS) technique. This is a dynamic version of the NWS MOS approach that can be applied to any numerical weather prediction model fairly quickly. Each forecast module produces, as best it can, a complete forecast consisting of forecasts for every variable at every site at every forecast lead time.

The DMOS approach has been applied to the ETA and AVN models. The MOS equations for each model run are recalculated weekly. In generating the regression equations, only the model runs and observations from the last 100 days are considered. The main advantage of this approach is that within 3 months any new model can be added to the system. For example, while no ETA MOS guidance is yet available, ETA DMOS forecasts have already been contributing to the system. Also, this DMOS guidance is available at any observing site.

A major disadvantage of the DMOS approach is that the regression equations generated are less stable than their NWS counterparts. Extensive quality control efforts must be applied to ensure that erroneous forecasts do not sneak through. A simple first step in this QC procedure is to not allow any regression equations whose r-squared scores do not meet a high threshold. When this situation is detected, “default” equations are used instead. These default equations attempt to capture the logic a meteorologist would apply if faced with having to come up with a forecast based only on the model data.

All the forecast modules’ forecasts need to be merged into a single final forecast. A process called the integrator is responsible for this combination step. This adaptive fuzzy logic process performs a bias-corrected, confidence-weighted average of the forecast modules’ predictions.

$$F = \frac{\sum c_i w_i f_i}{\sum c_i w_i} + B$$

Here the integrated forecast F is calculated by weighting the individual forecasts f_i by confidences c_i and weights w_i. The confidences are a measure of how well each forecast module felt it performed its job. The weights represent the historical skill of each forecast module. A different weight vector exists for each forecast variable, for each site, and each forecast lead time.

Each day the weights are modified to reflect the changing skill of the forecast modules over time. The forecast modules that have been doing well get more weight, and the poor performers lose weight. This happens by adjusting the weight vector by a small amount in the gradient direction of the error in weight space.

The integrated forecasts are passed on to the post-processor where quality control checks are performed. Also, other variables can be derived here from the “core” forecast variables. For example, relative humidity can be derived from air temperature and dew point rather than being predicted separately.

The post-processor also provides spatial and temporal interpolation capabilities. Since the core forecasts are created on 3 hour intervals to match the models’ output interval, temporal interpolation is necessary to produce hourly predictions. Spatial interpolation is used to generate forecasts at the non-observational sites.

Finally, these final forecasts are combined with non-verifiable variables, formatted appropriately, and made available to the road condition modules. These non-verifiable variables, such as sub-surface temperature, are not available in the current observational data sets and are required by the downstream Road Temperature algorithms. Making use of the forecast engine does not make sense if the system cannot tune itself using verification data. Since highway Environmental Sensor Station (ESS) data are not yet incorporated into the system, these fields are extracted out of the models and passed on unmodified.

These weather forecasts are combined with roadway data to create high-resolution forecasts of road-specific variables such as road temperature and net mobility. These road state data can be used to automatically generate recommended highway maintenance procedures using standard rules of practice.

This weather and road state information will be integrated with the recommendations into a display system made available to a road maintenance manager. This display will provide an overview of potential upcoming operations and serve as a starting point for the development of an operational plan. Hopefully this integrated system will become the basis for a valuable decision support system that will improve winter road maintenance service to the public.