Application of a Road Weather Information System

Torbjörn Gustavsson, *Göteborgs University, Sweden*

Data from road weather information systems (RWISs) are used to plan winter maintenance activities. RWISs provide measurements of air and road surface temperature, air humidity, and precipitation. Models are available and in practical use in Sweden for both obtaining temperature information over stretches of road and forecasting road surface temperatures. The temperature information is calculated by using a local climatological model, which is run on a topoclimatological basis. Through a division of the road stretches into segments according to variation in topography, vegetation, construction material, and weather, different temperature patterns are calculated. The input for the model is temperature data from the field stations. The forecast model is based on a combination of statistics and energy balance calculations. The prognosis is calculated individually for each station so that local effects may be considered. The input to the model is given from the RWIS and a cloud forecast is also needed. A presentation of a winter index model, which can be used to calculate the need for maintenance activity in an area, is included.

The idea behind a road weather information system (RWIS) is that field stations measuring air and road surface temperature (RST), humidity, and precipitation should be located so as to allow early warning of road icing. Various topographical areas and road sections with varying road construction must be covered by the system. Weather conditions produce varying temperatures; for example, during clear, calm nights the lowest surface temperatures are found in valleys, but during clear days screening effects are the most important consideration. The relationships among topography, weather, and temperature variation have been a subject of intense research carried out at the Department of Physical Geography in Göteborg, Sweden. Knowledge gained in this research has in several ways helped in the development of today's RWIS in Sweden. This paper focuses on three of these applications.

First, the forecast of temperatures and slipperiness risk, to assist maintenance personnel in their decisions concerning winter road activities, is described. Also important is valid extrapolation of the temperatures given by field stations to entire road stretches. This can be done with a computerized model described in this paper. Third, how winter statistics can be calculated by using the stored data from the field stations in the RWIS is described. The theoretical background of the RWIS is described by Bogren elsewhere in these proceedings.

RST Forecast

In Sweden a combined energy balance and statistical model is used to calculate RST for the coming 1 to 4 hr. The relatively short forecast time is useful in guiding road maintenance personnel in decisions regarding salting actions and other operations. Other advantages of such a short forecast time are that the accuracy of the calculation can be high and that the model is thus more sensitive to rapid weather changes.

By use of a combination of energy balance modeling and a statistical model, all major factors controlling the RST can be determined. The radiation components are covered by the energy balance model and, in combination with an external input of the cloudiness, an effective radiation is calculated. The statistical part allows the local topography to be taken into account, along with the road construction materials, surface coating, and so forth used at each station site.

The cloud forecast, which is fed into the model, is a prognosis of the effective cloud cover, that is, cloud height and type in combination. The grid-net resolution is 4000 m, in accord with the requirement to consider the local conditions at each station site.

The forecast model has been tested against measured data from field stations located in various environments. An example is shown in Figure 1. The 2-hr RST forecast is plotted against the observed RST value. The straight line in the diagram shows the 1:1 relationship and the dotted line is the 1°C deviation. A total of 1,344 observations was used for this month. The test showed that the model is well suited for the type of information needed by the local maintenance personnel and that the correlation is high between observed and forecast temperatures. An advantage of this model is the low costs for both adapting and running it. The forecast model takes advantage of the measured parameters at the actual field stations and the only external input parameter is cloudiness. Current research by the Swedish Meteorological Office will automate this process with computerized intrepretations of satellite pictures and other information.

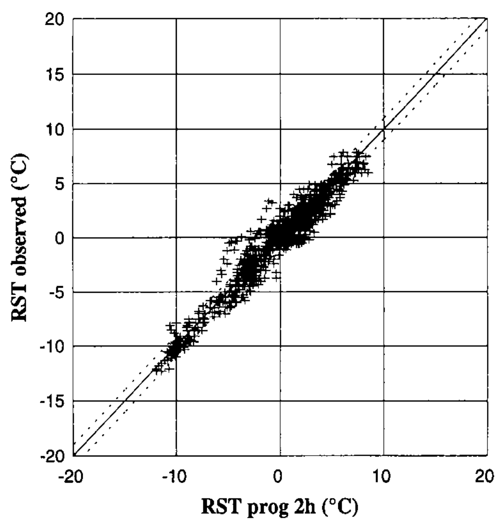

FIGURE 1 Plot of forecast versus observed RST for Station 1403, February 1993.

Compared with this semiautomatic model, other models require many more input parameters, including those measured at meteorological stations—precipitation, clouds, wind speed and direction, and air and surface temperature (*1*). This limits the models' ability to make forecasts for various areas. Also, running costs are high.

Further development of the RST forecast model includes a model for forecasting the dew point temperature and interaction with a regional model to improve correlation between the regional weather and the forecast for each station site.

Local Climatological Model

The idea behind an information system with field stations is, as previously described, that the stations should be located in various local climatological environments. Extrapolation of the data for large areas is not possible without consideration of topography, weather, and so forth.

By using historical data from the field stations and mobile temperature recordings along the major road stretches, a computerized model has been developed by the Department of Physical Geography (*2*). This local climatological model (LCM) uses topoclimatological principles to calculate temperatures between field stations. Road stretches are subdivided into segments according to the local climatological parameters that are the most important for a fixed combination of time of day, time of year, and prevailing weather conditions. Calculation algorithms are further linked to the segments.

During the winter of 1995–1996 a combination with a cloud forecast was tested as input data to the model. This information allows the area to be subdivided according to prevailing weather. Previously, the variation in temperature between the field stations was used to determine what type of algorithm to use for the extrapolation of data. With the development of the LCM, a more complete coverage of the weather parameters is achieved. Analyses and tests carried out during the 1995–1996 winter season showed that accuracy had increased and that the cloud forecast could be most helpful in decisions regarding the local variations in weather.

During the operational run of the model, questionnaires were delivered to model users. Users were asked to give their views of the model's usefulness, accuracy, presentation, and so forth. Their responses, along with analyses of stored data and detailed measurements carried out in the test area, will be most helpful in the development of the model.

The questionnaires indicated that maintenance personnel using the model found correspondence between the LCM and the field station was good, that the LCM added information concerning the susceptibility of various road stretches to icing, and that the LCM was especially useful during slipperiness due to sublimation. This is because a varying temperature pattern causes the risk of slipperiness to vary a great deal.

WINTER INDEX

Studies of the geographical variation in road icing (*3,4*) have shown that the most diversified pattern can be found over an area the size of an average county. Topography and road construction are two of the most important parameters that account for this variation.

Through analyses of stored data from RWIS stations, it has become possible to conduct detailed studies of winter weather and the associated maintenance needed to keep roads free from ice, snow, and the like. Use of winter indexes, along with historical RWIS data, is one way to gain information about the winter season as it relates to the number of road icing conditions. The indexes can be used to calculate both the spatial variation in the need for maintenance activity and the severity of a specific winter. This approach is especially useful for calculating different types of slippery conditions and associated maintenance needs.

The GAB index sums the occasions with snow, frost, and black ice. According to the description of different types of road icing, these three represent the categories of road slipperiness that may be detected by an RWIS. This index was developed in Sweden to meet the demands of maintenance personnel concerning a separation of the needs for winter activity in different areas. The formula is as follows:

$$GAB = \sum A * \text{snow} + B * \text{frost} + C * \text{black ice}$$

Snow (or rain, provided the surface temperature is below 0°C) can be divided into subgroups depending on the amount of snow. The smallest increment to increase the index value is 20 mm. Frost is the number of occasions with risk of frost formation, at least a 2-hr duration with a time interval of at least 4 hr. Black ice is the number of occasions on which temperature drops from above 0°C to below 0°C and the surface does not dry (checked against humidity and occurrences of precipitation). The temperature drop must be from at least +0.5°C to −0.5°C.

All parameters in the index are given the value 1 if the criteria are fulfilled; otherwise they are 0. The summation is carried out daily and could be given for the whole winter season or a shorter time period if required. A, B, and C are weight functions that can be related to the cost of maintenance activity. It is also possible to change the influence of the three parameters to reflect their importance in a specific area or road stretch. For example, large roads with much traffic require faster action than smaller roads, and therefore the need for maintenance activity may be much higher.

The time interval for frost and black ice occasions is set to 4 hr. This is based on studies that show how long salt-

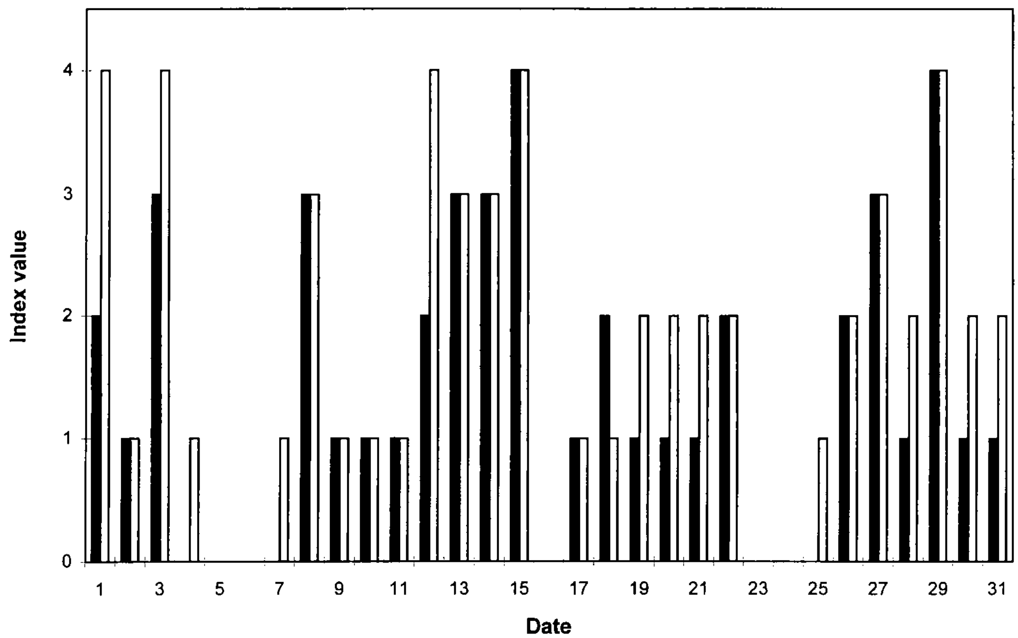

FIGURE 2 Calculated GAB index values for two field stations, showing variations in maintenance needs.

ing effects may last on a road. The decline of salt amounts on the road has been shown to be related to weather, state of the road surface, traffic, and so forth. In theory, four different frost situations may occur in a 24-hr period, with a total of six temperature drops from above to below freezing. The snow criterion relates to the amount of snow; at least 20 mm must be recorded before action must be taken. As a result, the snow parameter may occur several times during each day. Snowfall often requires a number of salting and plowing operations to keep the roads free from snow and this must be accounted for in a fully developed index. This can be achieved, for example, by giving the snow event a higher ranking than the other events.

Figure 2 shows how the GAB index may be used. The number of slippery events is summarized for each day during December 1994 for two stations. In the example the index value differs for the two stations because of their local climatological siting. Performance of calculations like this allows the need for salting activities in different areas to be compared.

In a study by Gustavsson (*5*), it was concluded that a winter index that can be used in relation to winter maintenance activities should

- Show a relation between the summation of different parameters related to slipperiness and the need for maintenance activity;
- Give a number that allows interpretation on physical grounds, in addition to comparison with other time periods;
- Have a proper time resolution so that only occasions and that call for action are included in the summation;
- Relate a weight function, if used, to either the cost or the need for activity during the specific occasion.

References

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