Road Weather Service System in Finland and Savings in Driving Costs

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The Finnish National Road Administration has developed a road weather service system that produces weather information for both road maintenance personnel and road users. The measuring data of road weather stations and the service of the Meteorological Institute (forecasts and radar and satellite pictures) are transmitted to users' workstations in real time. All the data are combined and shown in visual form. The real-time system also includes an alarm call system for when the weather development exceeds the determined limits at certain road weather station. The service system enables communication between two workstations or a workstation and a central station for real-time information transmission concerning salting operations and such. In the first phase, the system was built mainly with the needs of maintenance personnel in mind. The objective is to improve the monitoring of road weather conditions so that winter maintenance can be carried out systematically and at the right time. The main benefit is the possibility to anticipate the road surface freezing and thus eliminate accidents caused by slipperiness. The road weather information can also act as an impulse for the traffic signs to change according to the weather. The benefits of driving costs consist of the savings in accident costs, vehicle costs, and time costs. The service system gives good real-time information and forecasts of the road condition, so the time that the roads are slippery can be shortened and accidents eliminated. Prompter salting or plowing will improve the trafficability, and driving time will be shorter than it would be without the road weather system. Plowing at the right time affects the thickness of snow and slush on the road. The duration of slippery road condition has been estimated to shorten 10 to 30 min per deicing activity in Finland. Each of these effects results in savings in driving costs.

The Finnish road weather service system is an automated information system that sends actual and forecast weather and road surface information to those responsible for road maintenance. The road weather observation network provides information about weather and surface conditions on all the main roads (Figure 1). At given time intervals, weather forecasts and radar and satellite pictures are received from the Finnish Meteorological Institute. Plain-language observations of surface conditions can also be collated and sent to various users. The data are shown on a versatile screen display that users can easily manipulate to suit themselves. The system also contains a warning facility that produces an alarm whenever given critical weather threshold values are crossed. The alarm is automatically communicated to selected paging devices or telephone numbers. All users of the system are in direct contact with each other by electronic mail. Reports of weather and road conditions are easily communicated to external systems, such as those serving road users.

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ROAD WEATHER SERVICE SYSTEM IN FINLAND

The road weather service system in Finland consists of 11 central stations, about 200 workstations, and about 150 observation stations. The workstations and the observation stations form a network covering all of Finland (Figure 1). The system has also a connection to the computer system of the Meteorological Institute, which supplies the system with weather radar and satellite images and weather forecasts. The system sends back information based on the observation station measurements.

The maintenance of the road network on Finland is organized in districts, and each district is responsible for the roads in its area. The district central stations collect information from the observation stations in that district. The information from the observation stations is shared among the central stations. The radar and satellite images are spread to all central stations and thus are available to all workstations in the system (Figure 2).

FUNCTIONS OF ROAD WEATHER SYSTEM

The functions of the central station are configuration, information gathering, communication between the workstations and the central station, and alarm handling (Figure 3).

Configuration

The operation of the system is based on the parameter settings in the central stations. The configuration application is used to determine and update the system parameters. The application is menu-driven, and data are updated in an easy-to-use form. The configuration parameters are the connected observation stations, the connected workstations, the alarm set, the alarm threshold values, the alarm warning addresses, and the active sets of sensors in each connected observation station. The system also includes configuration files that contain information on direct data lines, X25 and telephone lines, and information on other connected computer systems. Every file has a menu option to start the editing.

The parameters identifying a central station include a code number, name, and location. The parameters identifying a workstation include a code number, name, security classification, and type of connection channel. Other information can also be added. The parameters identifying an observation station include a code number, name, security classification,

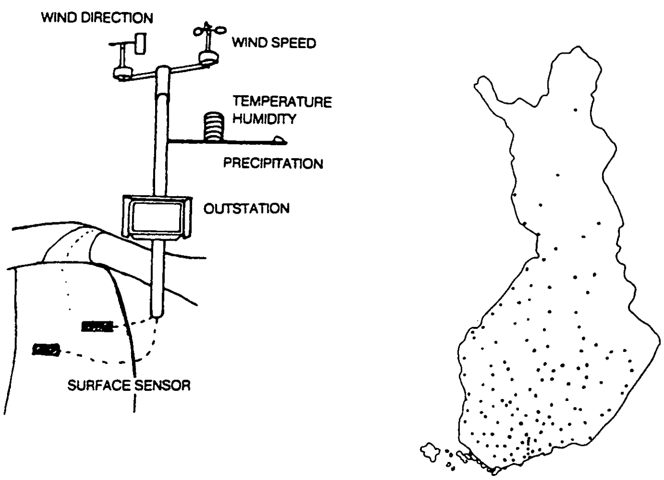

FIGURE 1 Observation station and network.

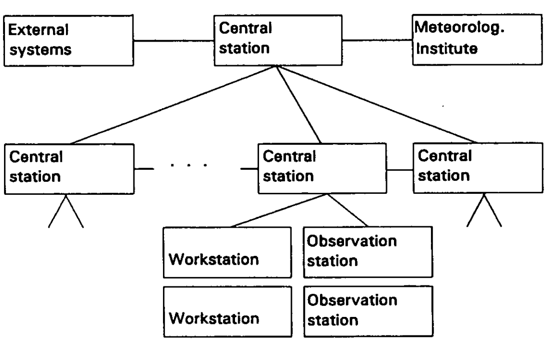

FIGURE 2 System overview.

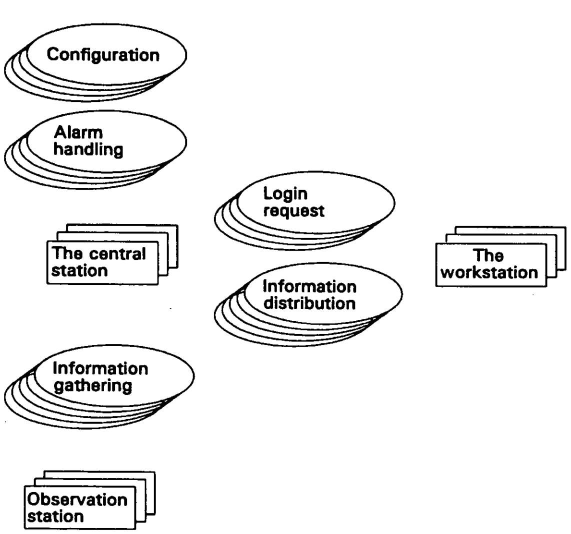

FIGURE 3 System functions.

type of connection channel, data-requesting interval, active sensor information, and location coordinates.

The parameters connected to a sensor include a code number, name, security classification, and eventual additional information. An arbitrary filtering function can be attached to each sensor. The functions can also refer to raw or filtered data of the other sensors. The user can define textform definitions corresponding to numerical sensor value domains.

The parameters that determine the structure of the records sent to workstations include codes of the sensors and the destination workstation. In one record, values of a maximum of 20 sensors can be included. A record can consist of either observation data or forecast data, but not both.

For every alarm, the following parameters are specified: alarm identifier, alarm level, alarm address, alarm triggering, and time period within which the alarm limit is being evaluated—for example, icing alarms can be set off during summertime. The observation stations for which the alarm is active are also specified. The alarms are classified by alarm level. For each level a different alarm address can be specified.

The configuration application also includes other system support functions, such as archives and backup utilities, startup and shutdown programs, communication, and overall operation monitoring applications.

Information Gathering

Information gathering is a continuously running background process that sends the data requests to the observation stations at time intervals specified in the system parameters. The time intervals may change as alarm threshold values have been exceeded.

When data from an observation station have successfully been received, the process evaluates possible filtering and alarm triggering functions and forms the records to be sent to the workstations. When an alarm is triggered, the process sends an alarm message to the alarm address according to the alarm level through the alarm handling application.

Communication Between Workstation and Central Stations

The information distribution application sends the formed data records to the workstations at time intervals specified in the system parameters. When the central station contacts a workstation, the workstation requests data records needed for its end user applications. The transfer application checks the security classification of the requested data and sends the permitted records to the workstation. Only the newest lacking information is transferred. The data transferred to workstations consist of sensors data records, radar and satellite images, forecasts, text weather reports, alarms, and electronic mail.

A workstation connects itself to a central station by sending a log-in request to one of the log-in lines of the central station, which are continuously polled by a log-in background process. During the next data distribution cycle the central station contacts all the active workstations. This connection principle ensures that unauthorized users of workstations are not able to break into the central station.

Alarm Handling

The alarm-handling application sends the triggered alarms to corresponding addresses. An address can be a workstation code or a telephone number of a pager.

SOFTWARE ARCHITECTURE

Application Modules

The central station software is written in C-language in the UNIX operating system environment. The information is stored in an Oracle data base. The central station system consists of several program modules. Each module independently performs a specified task. Three types of modules exist: continuously running background processes, modules started up by other modules, and modules initialized with user menus.

Alarm server is a background process that receives triggered alarms and sends alarm messages to corresponding alarm addresses. Observation station polling is a background process that collects the observation station information at given time intervals. The module also evaluates the filter and alarm functions and activates the alarm server when needed. The process forms the data records to be sent to the workstations. When collecting information from a certain observation station, the polling process starts a collection process depending on the communication channel used for transmitting the data from the observation station. Communication can be made by X25, modem line, or direct line connections. Observation data from other central stations are read with another module. After every successful observation station contact, the polling process starts the calculation process, which performs the defined mathematical functions to the sensor data.

Workstation polling is a background process that controls the workstation communication. The module establishes the connections and transfers data records to active workstations at given time intervals. The actual data transferring is done by subprocesses started by the workstation polling process. The chosen process depends on the communication channel in the same way as described in the previous section (X25, telephone lines, direct lines).

Workstation log-in is a background process that polls the log-in lines for workstation log-in requests. The process sets the workstation, which is requesting the data, in an active state after a successful identification.

Data Base

The data base of the system is implemented with Oracle 6.0 data base software tools. The data base operations are carried out with standard SQL embedded in C-language application programs. The information stored in the data base consists of configuration information and observation station measurements.

When the central station system is started, the configuration information is loaded in the shared memory of the system. The application programs use this shared memory data to make data checks and verifications. The mechanism grants maximum system performance.

The information collection application stores sensor measurements in the data base; information on triggered alarms is also stored. The formed data records to be sent to the workstations are written into files, which are in observation station–specific directories. The ready-made records are stored for a specified period, or at least for 24 hr, so the most recent and most frequently used information is in an easily and quickly obtainable form.

It is possible to access the data base directly with any Oracle data base tool, such as interactive SQL-interface or SQL*Forms.

User Interface in Central Station

The user interface of the central station is developed with the D-Screen user interface toolkit. The system is operated with a menu-based user interface. The system operates normally in the background even when the user interface process is not active. The user interface is used for updating configuration settings and for system maintenance. The menu system has options to start the configuration information forms, file editing options, monitoring screen options, and backup utilities.

Communication Software

The communication between the central stations and other computer systems has been implemented with Internet supporting Transmission Control Protocol/Internet Protocol (TCP/IP)–based services provided by the UNIX operating system. The services include remote execution of programs and the file transfer. The data are transferred through Ethernet and X25 networks.

The communication between the central station and the observation stations and workstations has been implemented with the ICECAST communication protocol developed especially for this purpose. Before the transfer, the data are packed, numbered, and framed with identification information. After receiving a data packet, the receiver unpacks and verifies it. The information in the packets is verified using checksum. If no transfer errors are found, the receiver confirms the transfer. If the confirmation is not received, the packet will be sent again.

SAVINGS IN DRIVING COSTS

Introduction

The main purpose of the road weather system is to improve the management of road and weather conditions so that winter maintenance can be effectuated systematically and at the right moment. When the costs and benefits of the improved road weather service are calculated, losses and gains associated with driving costs, road maintenance, and environmental, social, and psychological effects should be taken into account.

Benefits of Road Weather System

The main benefit of the road weather system is its potential to anticipate the freezing of the road surface and thus eliminate the accidents caused by slipperiness. The duration of slippery road conditions can be shortened. Another safety benefit is that drivers can be warned of poor road conditions via different forms of communications, thus decreasing accidents.

Trafficability will improve because of better road conditions, in turn benefiting driving time, fuel, and the environment. Other, direct benefits can be achieved by better methods of maintenance, including

- Work organization,
- Material amounts,
- Watchover, and
- Systems.

Costs of Road Weather System

The costs can be divided into two parts: the road weather observation and data processing system (includes also radar and satellite data), and the forecasting system and service.

Method To Calculate Benefits

The savings associated with only road maintenance (salt reduction, personnel organization, etc.) can be calculated by comparing the costs of the maintenance activities with a road weather system to those without any special weather service. Environmental, social, and psychological benefits are very difficult to determine, but they are still significant to the public.

In this connection, maintenance savings are not estimated but the headlines are made to estimate the benefits that can be achieved in driving costs. Such benefits can be represented as the benefits of each part of the driving costs:

driving costs = accident costs + vehicle costs + time costs

Savings of Accident Costs

One effect of the road weather service system could be to begin salting 50 percent sooner—for example, if salting normally begins 3 hr after confirmation of the change in road conditions, it would now begin 1.5 hr after confirmation. This kind of improvement in maintenance activities would decrease accidents 3 to 17 percent depending on the district and the winter (*1*). The accidents (fatalities, injury, damage to vehicles) are evaluated differently in every country [e.g., in Finland one fatal accident costs about 8 million Finnish marks (2)].

$$S_{\mathrm{acc}} = \sum_{k=1}^{3} (\Delta R_k * \mathrm{UC}_k) * \sum_{i=1}^{n} \left[(F_i * \Delta t) * \sum_{j=1}^{m} (L_{ij} * \mathrm{ADT}_{ij}/1440) \right]$$

where

S_{acc} = savings of accident costs;
ΔR_k = R(ice) − R(dry) = change in accident risk (scale:number of accidents per kilometer);
UC_k = unit cost of accident (estimated value);
k = type of accident [1 = fatal, 2 = injury (without 1), 3 = all (without 1 and 2)];
F_i = number of deicing and plowing activities per year per maintenance district;
i = maintenance district;
ΔT = decreased time of slippery road conditions due to prompter deicing activities;
L_{ij} = length of road network;
j = road category;
ADT_{ij} = average daily traffic per maintenance district and road category;
1,440 = minutes in 24 hr.

The activities occur randomly during morning and evening hours. Changes in traffic during activities do not cause effects, and the change in road conditions (icy-slush-wet-dry) is simply from icy to dry.

Savings of Time Costs

Quicker salting or plowing will improve the trafficability, and driving time will be x minutes shorter than without the effect of the road weather service system—which means savings in driving time.

$$S_{\mathrm{time}} = \sum_{z=p}^{t} \Delta \mathrm{TC}_z * \left\{ \sum_{i=1}^{n} \left[(F_i * \Delta T) * \sum_{j=1}^{m} (L_{ij} * \mathrm{ADT}_{ijz}/1440) \right] \right\}$$

where

S_{time} = saving in time,
$\Delta \mathrm{TC}_z$ = saving in time costs when speed goes from 80 to 90 km/hr,
p = passenger car,
t = truck,
ADT_{ijz} = ADT_{ij} by type of vehicle, and
z = car (p) or truck (t).

Savings of Vehicle Costs

Plowing at the right time affects the thickness of snow on the road. The thickness of snow from 0 to 8 cm causes a 0 to 10 percent increase to vehicle costs (fuel, etc.). If we can show how much the mean thickness of snow decreases during snowfalls by means of the road weather system, we can calculate the benefits of vehicle costs.

$$S_{\mathrm{veh}} = \sum_{z=p}^{t} \left\{ \sum_{i=1}^{n} \left[(F_{\mathrm{p}i} * \Delta T_{\mathrm{p}}) * \sum_{j=1}^{m} (L_{ij} * \mathrm{ADT}_{ijz}/1440) \right] * \Delta \mathrm{VC}_z \right\}$$

where

S_{veh} = savings of vehicle costs,
F_{pi} = number of snowfalls that cause plowing,
ΔT_p = estimated time savings when starting to plow, and
ΔVC_z = saving in vehicle costs.

Problems

The costs of the road weather system can be calculated exactly, but the benefits are only theoretical approximations. It cannot be found out exactly how much the road weather service will shorten the time of slippery road conditions.

Example of Calculating Benefits in Finland

There are 13 road districts in Finland. The total length of public roads is 76 000 km. There are 7437 km of main roads (first class). About 7 percent of the main road network goes through the Kymi road district.

Costs of Road Weather System

The costs can be divided into investments and yearly costs. The system, software, and hardware are investments. Maintenance of the system, forecasts, and radar pictures and the costs of the communications are yearly costs.

The investments of the system are about $4.3 million for the whole country; if the investments are allocated per 6 years and 13 districts, that is $60,000/year/road district. The yearly costs are about $140,000/district. So, the total costs of the system for the Kymi district in a year are $200,000, and $370/km of main road.

Benefits of Road Weather System

In deicing activities, the road masters estimated the average time saved at 23 min/activity (10 road masters in Kymi district, experience of one winter). The average price of an accident is calculated to be about $60,000 in Finland. The change in the accident risk between icy and dry road conditions is, according to the research in Finland, 5.8 accidents per 1 000 000 km. (The average daily traffic varies from 1,000 to 10,000 on that road network.)

Because of the quicker maintenance with the road weather system, the benefits calculated by the equation in the Kymi district are as follows:

Type of Cost	*Amount Saved ($/year)*
Accident	900,000
Time	60,000
Vehicle	20,000
Total	980,000

Thus the cost-benefit ratio is about 1 to 5 in the Kymi road district, which, with respect to the climate and the traffic, is a typical road district in Finland.

REFERENCES

1. *Talvikelien onnettomuusriskit II* (in Finnish). TVH 741843. Helsinki, Finland, 1987.
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