Winter Maintenance in the Netherlands

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Traffic and transport are of vital importance to the Netherlands. The country has an average winter temperature of just above 0°C, and winter maintenance is important to keep roads open and safe. The organization and strategy of winter maintenance are discussed. Special attention is given to the National Ice Warning System, which has been installed on highways and secondary roads in the Netherlands. This system, along with regional weather reports, weather radar, and road-surface forecasts provided by experienced meteorologists, gives authorities up-to-date road and weather conditions. The combination of winter maintenance, knowledge of road management, and meteorology appears to be a success in the Netherlands. In 3 years, Meteo Consult, a private weather service, has significantly enlarged its share in the market. Experience in the Netherlands has shown that free competition in meteorological assistance (which is not common in Europe) can improve quality in road management without reducing traffic safety or increasing cost.

Traffic and transport are of vital importance to the Netherlands. Because of its favorable location, the large ports of Rotterdam and Amsterdam, and Schiphol International Airport, the Netherlands is a main gateway to Europe. Roads and waterways are essential elements of the transport system and account for a significant part of the Netherlands' national income. For the Netherlands to continue to be Europe's distribution hub, the infrastructure must be efficient to use.

Transport is and will continue to be a growth sector. The continued unification of Europe moves markets. The extension of the European Union and the fading of the borders with Eastern Europe will accelerate this process. Consequently, investment in infrastructure, safety, and environmental protection has become a priority for the present government. A population of 15.5 million in only 41.6 km^2, 6 million cars, 500,000 vans, and 90,000 trucks all seriously test the capacity of the Dutch road system.

The activities necessary to keep roads clear and safe for driving during the winter months are explained, as is the interaction of the government authorities that coordinate winter maintenance in the Netherlands.

Climate

The Netherlands, located in northwestern Europe, has a maritime climate with relatively mild, humid winters. The warming effects of the Gulf Stream generate a predominately westerly wind, which in turn has a marked influence on temperature. Because of the high level of precipitation, which in the winter is mostly rain, road surfaces tend to be wet. Despite the relatively mild winters, the average January air temperature is 1.9°C. The changeable weather leads to hazardous road conditions,

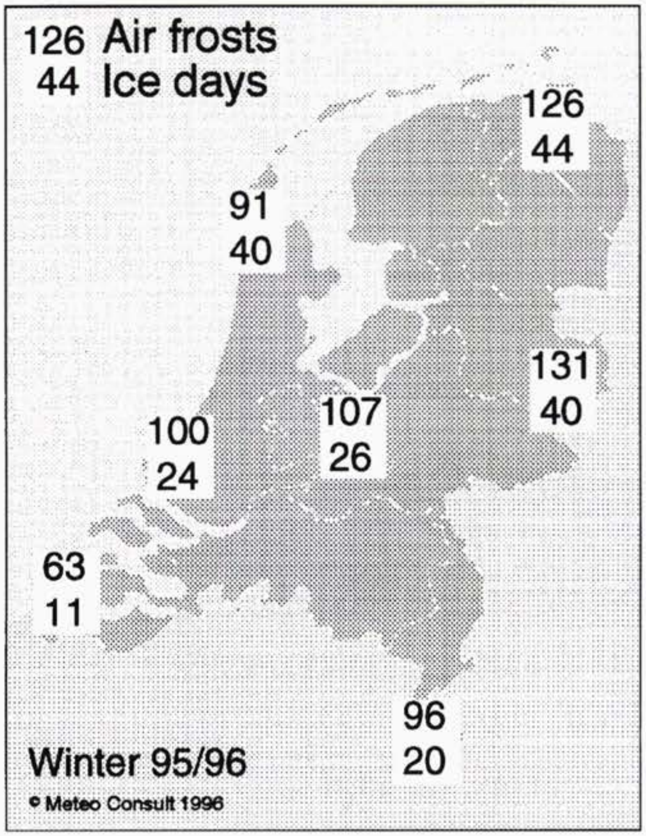

FIGURE 1 The climatological diversity of the Netherlands, winter of 1995–1996.

which mainly are caused by the freezing of wet sections as well as the formation of a layer of ice through condensation or freezing fog. Snow and freezing rain are infrequent. Winter maintenance mainly is based on the preventive treatment of highways and secondary roads by salting. In the colder Northeast, severe weather occurs considerably more often than in the warmer Southwest (Figure 1). High humidity combined with temperatures below freezing results in conditions that require the Dutch government to maintain a well-structured winter maintenance program.

Winter Maintenance Organization

The Netherlands has three government authority levels; each authority maintains its own road system. The public authorities maintain more than 2500 km of main roads, and the county authorities are responsible for about 50 000 km of secondary and tertiary roads. The municipalities maintain about 50 000 km of municipal roads.

The supervision of main roads is the responsibility of about 25 geographically based divisions. County authorities divide the maintenance and control of their roads into several areas. The municipalities are responsible for their own road systems and, together with the counties, also are responsible for bicycle paths (nearly 20 000 km), which are maintained as well.

During winter maintenance, all authorities are autonomous. However, public and county authorities consult each other regularly on an executive level; thus, the two levels of authority have established similar procedures for winter maintenance. The main goal is to prevent hazardous road conditions, and this is done through salt spreading. Both organizations use the prewetted technique for spreading operations. The public and county authorities both purchase or refurbish equipment and material (e.g., spreaders, snowplows, and salt) before the winter season begins and store these items in several locations for easy access during the winter months. The trucks needed for spreading operations (Figure 2) are rented from the transportation industry, and the drivers are hired from the same industry. The costs are based on a standard amount per year plus an amount for every spreading operation. If the spreading operation takes longer than 3 hr the costs relate to the actual hours worked.

Municipalities, on the other hand, use their own trucks. In the municipalities, the changeover from the dry salt technique to the prewetted technique has not been completed. About 70 percent of the larger municipalities use the prewetted technique. In smaller municipalities, the changeover has not made much progress.

Within the public and county authorities are generally three coordinators who take turns being on duty. When hazardous conditions first appear the coordinator informs one of the workers in each area. The truck drivers are contacted and they begin spreading operations. After the spreading operation, the driver returns to the area headquarters, and more spreading operations are ordered, if necessary.

With the help of a computer program, all spreading routes have been optimized during the last few years. The duration of a spreading operation on each route is about 45 min. The time it takes to alert the drivers, put

FIGURE 2 Truck with prewetting solution being loaded with salt in a maintenance yard.

the spreader on the truck, load the salt, and perform the spreading operation is a maximum of 2 hr. A fixed snowplow route takes about 1 hr to complete. Spreading is done mainly in the evening or just before the a.m. peak, to disturb traffic as little as possible.

The county authorities have a similar organization but take longer to spread, typically 1.5 to 2 hr for secondary roads.

In municipalities, where spreading operations are done by the local authorities, a clear difference exists between the time it takes a main road and secondary roads to receive treatment. Integration among routes is limited. In addition, organization of spreading and salt storage management is rarely integrated among authorities.

As mentioned, the prewetted technique is frequently used. In general, calcium chloride ($CaCl_2$) is the wet component used in prewetted spreading operations. Quantities of salt used depend on conditions.

Freezing of wet road sections caused by dropping temperatures is the most common form of road ice in the Netherlands. In general, this can be prevented by application of 5.5 g of sodium chloride (NaCl) per square meter. Porous asphalt (drain asphalt), which is often used for main roads, needs a higher dosage (11 g/m^2).

Road ice caused by condensation also may be prevented by the application of 5.5 g sodium chloride per square meter. The Netherlands road authorities use preventive measures as much as possible, especially for approaching snow or freezing rain. Fifteen g of sodium chloride per square meter prevents the snow from attaching to the asphalt. During snowfall, 15 to 20 g/m^2 sodium chloride is applied to the road surface right after plowing. Normally, a dry salt is used in this case. In the Netherlands both evaporated (vacuum) salt and rock salt are used. The heavy metals in the salt are limited to 10 ppm. In addition, the division of grains has its limit. The maximum permitted size is 3.15 mm. Larger grains are permitted when a price reduction is stipulated, as are fine materials.

Snow is removed from bicycle paths with a revolving broom instead of a snowplow.

National Ice Warning System

Prevention is the best policy for main and secondary roads. Without the required data regarding ice conditions, road authorities may order needless spreading operations, resulting in wasted money and resources. Adequate planning also reduces environmental pollution caused by the thawing agents. Porous asphalt requires special attention. Measuring points installed along sections of porous asphalt have improved the winter maintenance capability of road authorities.

In 1989, the first phase of the National Ice Warning System was installed. The experience gained led to a series of improvements, mainly in the reliability of the system. By the end of 1994 the ice warning system had been installed on all highways and on most of the county roads. The measuring points on the county roads often run in conjunction with the highway system. In addition, measuring stations have been installed on the municipal roads. The procedures and communication of the National Ice Warning System were fixed in functional specifications so that several contractors could participate in the project.

The ice warning system consists of several elements (Figure 3). First, the measuring stations along the road

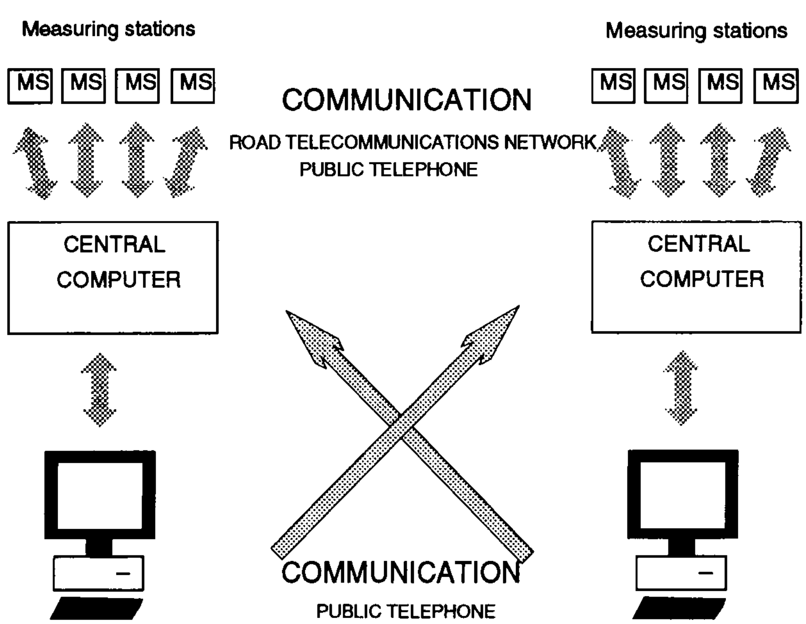

FIGURE 3 National Ice Warning System communication system.

collect relevant data measured on or near the road. The collected data are then retrieved by a central computer, either through the emergency telephone network or, if such a system is not available, through the public telephone network. The computer collects the data from measuring stations in its district every 5 min. If the data are transmitted through the public telephone network, they are collected once or twice every 24 hr. However, in situations in which road ice is likely to occur, the data are collected on a much more frequent basis. Of course, current data from measuring stations can be retrieved whenever the road authority in charge considers the data to be essential.

By using the public telephone network, all road authorities can establish a connection with the central computer with a modem-equipped personal computer. Through the telephone network, a connection to the central computer system can be obtained from anywhere. If hazardous conditions are expected in one or more places, the central computer, on the basis of programmed parameters, sends a semaphone or telephone alarm signal to the road authority in charge of the road sections involved. Because the parameters of the ice warning system produce alarm signals before the road actually becomes icy, authorities can carry out preventive spreading actions.

Communication between the personal computer and the central computer is standardized, which means that all the ice detection systems in the Netherlands use the same communication algorithms. As a result, road authorities can collect data for areas outside their own districts and use the data as a solid basis for their spreading decisions (Figure 4).

Measuring Station

The roadside measuring station is one of the most important elements of the National Ice Warning System. To determine the position of a measuring station, thermal mapping is carried out under prescribed conditions. These conditions include light winds, cloudless skies, and temperatures around freezing. Thermal mapping indicates the coldest spots of a specific section of the road system. The pertinent road authorities apply these data to their experience to establish the first areas of road ice formation.

The Netherlands' infrastructure contains many bridges and flyovers. Since bridges and flyovers receive no heat from the subsoil, they often are the first places to become icy. Yet, under certain circumstances, road ice easily develops in many other places, including elevated roads and roads near forests and large water surfaces. In addition, the low position of the sun in winter allows entrances and exits to highways, especially those on the north side, to become hazardous. Through review of these critical

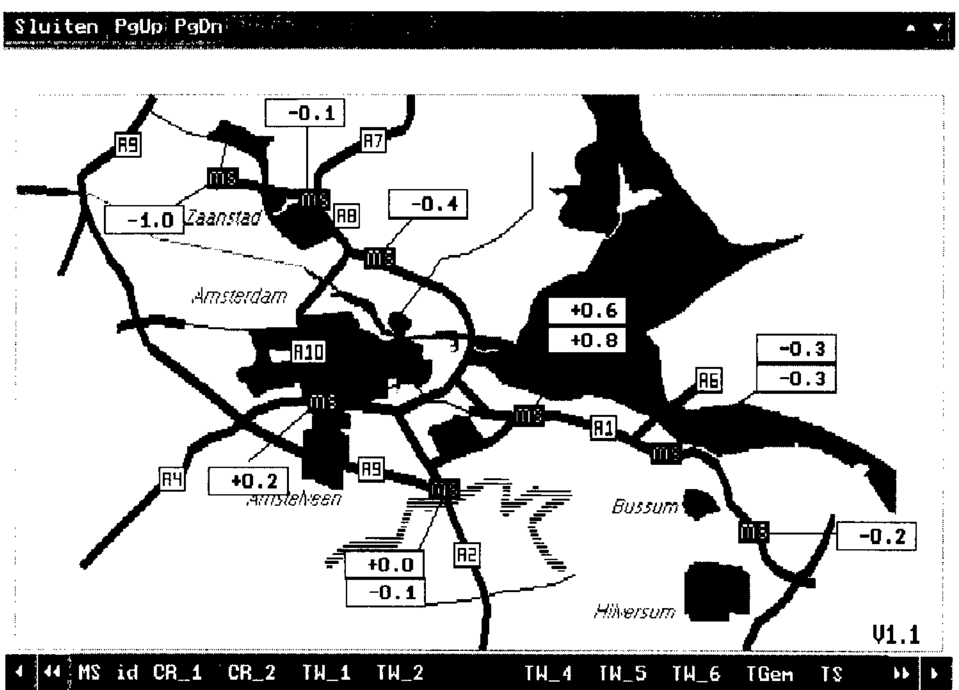

FIGURE 4 Road temperatures around Amsterdam, January 7, 1996, 8:30 a.m. Highest temperature is for a steel bridge. Measuring stations around the country provide such relevant data to road managers.

spots, a safe distribution of the measuring stations can be established within each district.

Currently, 300 measuring stations are situated on primary and secondary roads throughout the Netherlands. These computers are linked to 20 central computers, and the last central computer was installed in December 1994. Near the measuring stations, several temperature sensors are installed a little below the road surface. In the case of multilane superhighways, the temperature sensors are installed in the wheel track of the left lane; because of lower traffic intensity, this lane is colder than the more-traveled right lane. Moreover, the road is equipped with sensors that apply the principle of conductance to their measurements to provide information on the general condition of the road surface. These conditions may include a dry, wet, or salt-covered roadway. The temperature under the road bed is measured in several places. These values provide the road authority with information on possible warm or cold reservoirs in the subsoil. A maximum of 12 temperature sensors and condition sensors can be connected with a measuring station.

In addition to road surface data the measuring stations also record air temperature and humidity, as well as precipitation and, in some places, the speed and the direction of the wind (Figure 5). On the basis of air temperature and humidity values, the dew point is calculated. A comparison of the road surface temperature and the dew point indicates if humidity will settle on the road surface, which can cause road ice through condensation (Figure 6).

Decisions about spreading operations are made not by the ice warning system but by the road authority in charge. Because of the present parameters the road authority is warned more than 2 hr before hazardous conditions occur. On the basis of an evaluation made from the data provided by its own system and, if necessary, by adjacent ice warning systems, the road authority then makes a decision. In addition, meteorological forecasts play an essential part in the decision.

Sprinkler Equipment

The Netherlands abounds in waterways. Many bridges cross the country's rivers and canals, and a number of these bridges have steel frames. Especially during clear

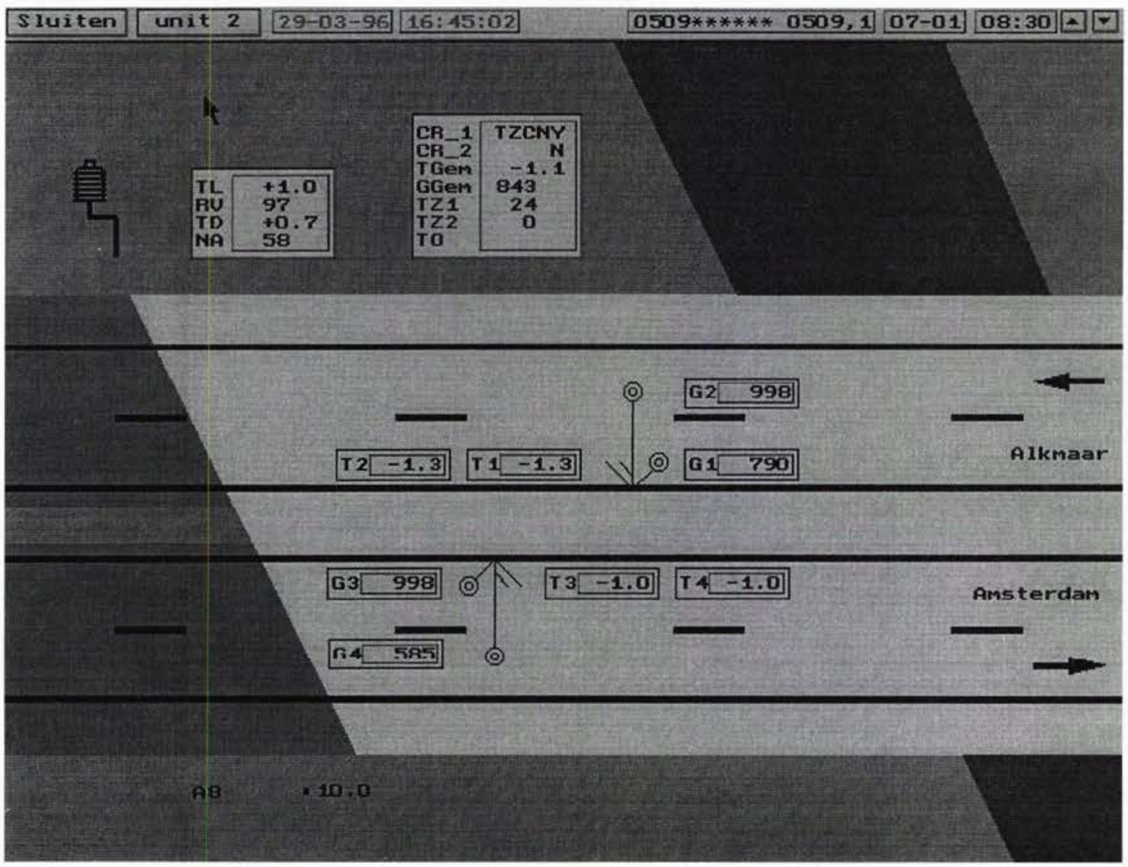

FIGURE 5 Illustration of measuring station, January 7, 1996, 8:30 a.m. Air temperature, humidity, dew point, and precipitation are shown in upper left box. Road temperature and conditions are shown at sensor locations in roadway. Note that road temperature is below freezing and air temperature is above freezing.

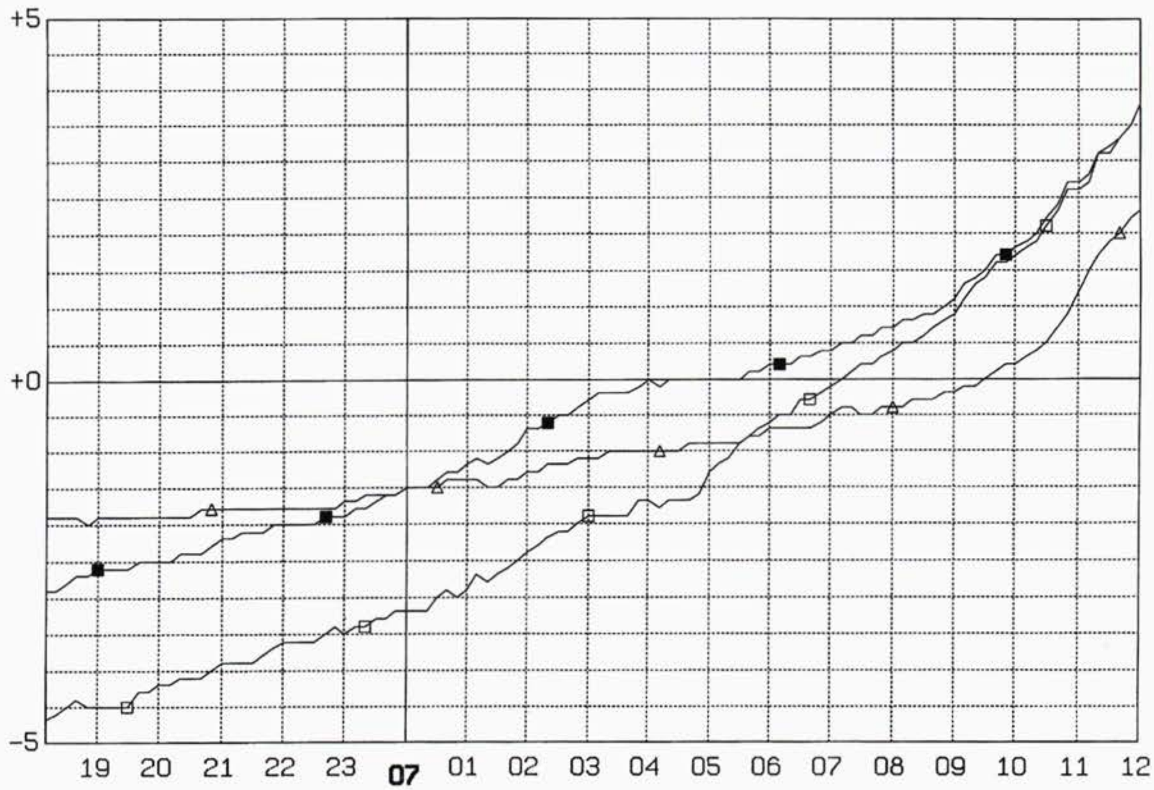

FIGURE 6 Road temperature (△), air temperature (■), and dew point (□) presented in graph form. Note that road temperature rises more slowly than air temperature. Road temperature passes freezing point 5 hr after air temperature.

and windless nights the temperature of the road surface of these steel bridges often drops below freezing, whereas the temperature of adjacent road sections may stay well above freezing. The humid maritime climate often causes condensation on these bridges. To the surprise of drivers, steel bridges often become slippery during spring and autumn. To prevent this, many steel bridges have been equipped with an ice warning system, which alerts the road authority to potential hazardous road conditions. Instead of sending a warning signal to a road authority, however, some ice warning systems independently activate a sprinkler system permanently located on the bridge (Figure 7). The sprinkler system sprays a 20 percent sodium chloride solution on the road surface. Five bridges have been equipped with the automatic sprinkler system, which has produced satisfactory results.

Meteorological Services

Several years ago there was little cooperation between road authorities and meteorologists. The most important source of information was weather reports broadcast on the news. Since then cooperation has accelerated and enormous progress has been made by combining the knowledge of road authorities with the knowledge of meteorologists.

All road authorities autonomously decide which meteorological products they need and who will supply

FIGURE 7 Sprinkler head spraying NaCl over bridge road surface.

these products. Road authorities often use several meteorological products provided by their meteorology firm to obtain information about conditions that may favor dangerous winter road conditions.

Regional Weather Reporting

One product developed by meteorologists for road authorities is a regional weather report. This report, which details the possibility of road ice, was developed by meteorologists by using knowledge of the types of hazardous roads in coordination with their experiences with weather conditions. The authorities receive a detailed report for the first 24 hr and a 5-day forecast detailing the possibility of winter conditions.

In addition to providing regional weather reports, meteorologists also warn road authorities of snow or freezing rain several hours before it reaches their areas. From that moment the road authority watches the situation with the help of weather radar.

Weather Radar

Radar pictures are available to all road authorities in the Netherlands (Figures 8 and 9). Through contact with the host computer, an updated picture is available every quarter of an hour. Detailed information about a specific area can be obtained by using the magnifying feature included in the program's package. By using the network of main roads, the road authority can relatively easily see the velocity and the direction of the precipitation. European countries do not exchange weather radar yet, so symbols are used outside the Dutch border. This system does, however, allow road authorities to increase their knowledge of current environmental conditions. During the 1996–1997 winter, road authorities used the German weather radar. Especially during an easterly circulation, these data considerably improve road-condition forecasts. The weather radar of Great Britain is not available to the Dutch market because it is too expensive.

Road Surface Forecasts

Many models for road surface forecasts have been developed. These models, which are based mainly on physical processes (e.g., balance of heat), considerably improved the "nowcast" (short-term forecast) conditions for the road authorities. In these models, data from the ice warning system are incorporated into the meteorological formula. From these models, nowcast

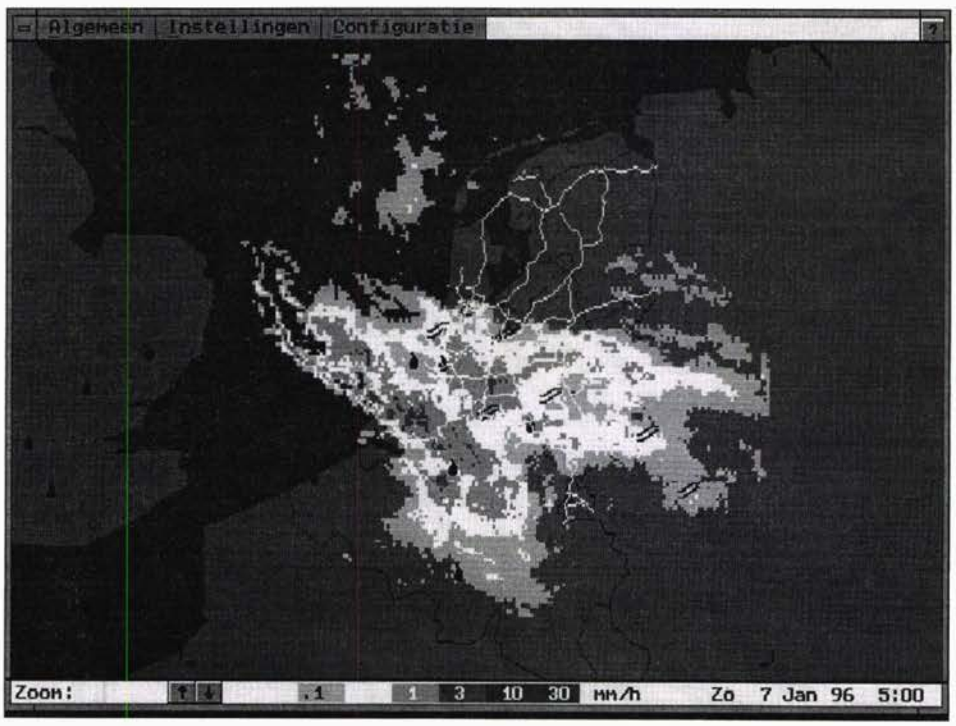

FIGURE 8 **Weather radar indicating freezing rain over southern Netherlands and rain over northern Belgium.**

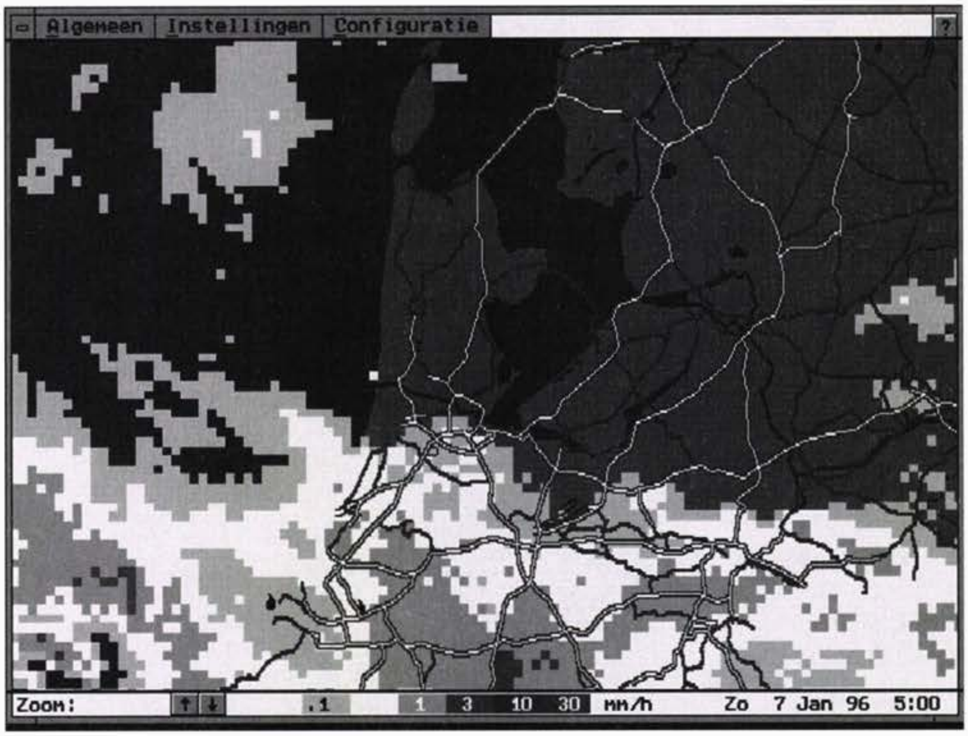

FIGURE 9 Use of road overlay to determine position of precipitation.

and long-term forecasts are generated for the road authority. To keep the information as accurate as possible, special measures have been taken. First, a meteorological database at Meteo Consult, a private weather service, is kept up to date with the most recent data 24 hr a day. In addition, the central computer of the ice warning system also gathers the data of the measuring stations.

When the road authority contacts the central computer, which is protected by a password security system, to get information from the ice warning system, the central computer immediately contacts the meteorological computer. Via a modern connection the actual data of the ice warning system can be passed on. The most up-to-date meteorological data can be connected to the ice warning system data and the model of road surface forecasts can present, in 1 min, the most up-to-date road surface forecast. Spreading decisions are based on this forecast (Figure 10). By using data from the winter of 1994, two road-surface forecast models used in the Netherlands were compared. The first, the icebreak model, was developed by Vaisal/TMI and is used by the National Weather Service. This model, based on physical processes, was compared to a statistical model, which was developed by Meteo Consult. It was clear that the statistical model is responsible for a more exact road surface forecast than is the physical model. It was further concluded from this comparison that a temperature sensor under the road surface construction is necessary to make correct road surface forecasts.

Designated Meteorologists

Increased knowledge of ice warning systems and meteorology encouraged a few divisions of the main road network to ask Meteo Consult for assistance in winter maintenance. Subsequently, seven meteorologists broadened their knowledge of winter maintenance and ice warning systems. During the winter, the meteorologists work 24 hr a day to ensure optimal operation of the ice warning system. The road authorities receive the collected data from the meteorologists. Decisions for spreading operations can be based on the data. During unclear situations, an inspection of the roadway is carried out following close consultation between the meteorologist and the road manager. Cooperation between road authorities and meteorologists has improved through this type of regular contact. The same seven meteorologists also are responsible for other meteorological services, such as regional weather reports.

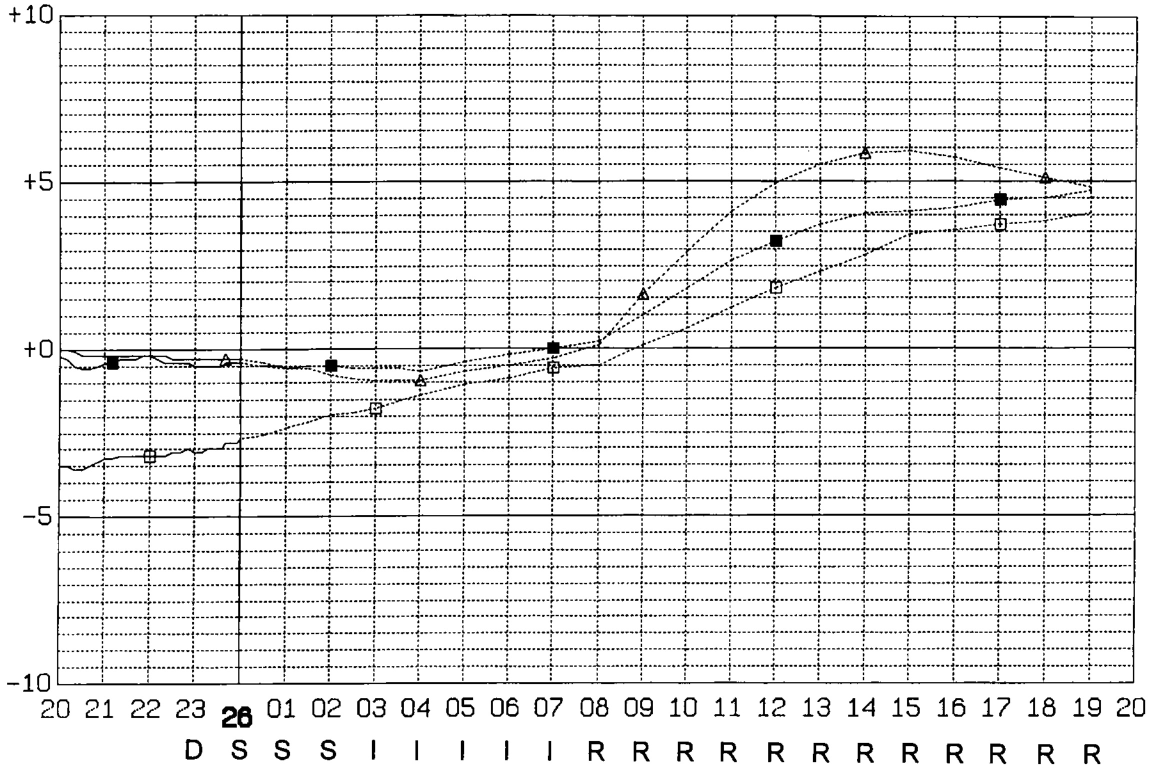

FIGURE 10 Four hours of measured data at the left (solid lines). Forecast from midnight on right (dotted lines). Road surface temperature (△), air temperature (■), and dew point (□) are shown. Forecast indicates snow (S) and freezing rain (I), followed by rain (R).

Conclusion

The combination of winter maintenance, knowledge of road management, and meteorology appears to be a success in the Netherlands. In 3 years, Meteo Consult, as a private weather service, has been able to enlarge its share in the market from 0 to 80 percent. However, in most European countries only one provider (the national weather service) is available to supply road authorities with meteorological services. Experience in the Netherlands has proven that free competition can improve quality in this part of road management, without reducing traffic safety or increasing cost.