

Use of Data on Road Condition and Weather for Winter Maintenance

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1 Introduction

A precise knowledge of roadway conditions and the ambient air facilitates the decision on commencing winter maintenance call-outs. Highway authorities in Germany thus use extensive sensor systems whose measured results are used for various purposes. They are incorporated in the medium and long-term forecasts (SWIS: Road Condition and Weather Information System) made by the German Meteorological Service (Deutscher Wetterdienst) which are primarily of interest for human resources planning on the one hand. This application is not discussed further in this paper. The measurement data is used for directly triggering call-outs (road weather systems) on the other. A third application consists in control of de-icing agent spraying systems.

2 Use of data on roadway condition and weather for triggering call-outs

2.1 Initial situation

Despite all the development progress made, meteorological services are, today, still unable to make weather and roadway condition forecasts for very small-area stretches of road (e.g. for bridges and valley sections etc.) incorporating precise times. The highway administrations use sensors to measure the relevant parameters in order to allow them to better monitor roadway and weather conditions at stretches of road which are particularly at risk. The measurement data recorded provides those responsible for providing meteorological services with information on the actual condition at the relevant measuring point. A further trend can be derived from the progression of the measurement data as a function of time. This trend may change very quickly only to factors including changing cloud cover and the position of the sun or shading which change during the day. It is not possible to derive a more precise estimate as to whether the existing trend will continue as previously from the data of one measuring point alone. This requires synoptic considerations including a knowledge of microclimatic parameters which still do not provide satisfactory results with state-of-the art technology.

Comprehensive assessment of the measurement data takes a great deal of time. The time required increases substantially if an area to be monitored includes many measuring points. Consequently, so-called skid-hazard warning models assist in assessment of the measured values faster. On the basis of the actual values and the progression of the data as a function of time, they derive skid-hazard warnings from which persons responsible for winter maintenance can draw conclusions on the possible skid hazard more quickly.

Those responsible for winter maintenance must distinguish between three possible forms of skid hazard with reference to the origin and of which a model should also provide a warning:

– **Skid hazard resulting from falling precipitation**

This skid hazard is produced by the impact of ice crystals on an undercooled roadway surface. The ice crystals are unable to thaw. Depending on the shape of the crystals, a distinction is made between a **slippery snow** or **freezing rain**. Rain which freezes immediately on contact with an undercooled roadway surface is also referred to as freezing rain.

– **Roadway frost**

The air is oversaturated with water. The excess water vapour is precipitated in the form of ice crystals (frost) at temperatures below 0 °C.

– **Black ice**

Water which freezes as the result of undercooling covers the roadway.

Some of the skid-hazard warning models offered in Germany do not warn against all forms of skid hazard. Various providers refuse to openly disclose the logic of the model offered. Skid-hazard warnings from these models cannot be reconstructed by and are thus not comprehensible to the user owing to the fact that the algorithms are unknown. For these two reasons, the Federal Highway Research Institute has developed its own model which can be made available to the highway administrations.

2.2 Model description

The parameters of roadway surface temperature, air temperature, dew point temperature and the roadway condition (dry, moist to wet, slippery) are included in the algorithms of this model. The aim of the calculation is to warn those responsible for winter maintenance at least 90 minutes prior to occurrence of a skid-hazard event. It is not the aim to provide them with a time span until possible occurrence of skid hazards. Such a specification is considered to be too imprecise for the reasons specified in Section 2.1.

The alarms issued by the system can be subdivided into four essential categories. They can split into “no risk of skid hazard”, “warning: skid hazard may occur soon only if the trend changes”, “warning: skid hazard may occur soon owing to the trends” and “warning of the risk of skid hazard which may occur immediately”. The reports are shown in different colours for faster assimilation. The differentiation results from the relevant roadway surface temperatures and their trend.

The first indication of the risk of skid hazard occurs even at a roadway surface temperature of +5 °C. This temperature has been selected since, on the basis of experience available, a temperature drop by more than 5 Kelvin, i.e. to the freezing temperature of water at 0 °C in this case, occurs only extremely rarely. No temperature drop exceeding 5 Kelvin within a period

of 90 minutes was recorded in a series of measurements conducted over two winter periods on a stretch of motorway.

The temperature trend is considered in the range of a roadway surface temperature between $+2\text{ }^{\circ}\text{C}$ and $+5\text{ }^{\circ}\text{C}$. If linear extrapolation of the measured values leads one to anticipate a drop in roadway temperature below the $0\text{ }^{\circ}\text{C}$ mark during the next 90 minutes, the risk of possible occurrence of skid hazard is indicated. If the roadway surface temperature remains above $0\text{ }^{\circ}\text{C}$ during the next 90 minutes on the basis of this consideration, only the following warning is issued: skid hazard may occur soon only if the trend changes.

The trend calculation uses the measurement data of the last 10 minutes. The onset of greater changes can be converted more quickly to a warning message using the data of this time span. However, even small trend changes lead to changing statements of the warning messages. If the measurement data of the last 60 minutes is included, it is possible to achieve a higher constancy of the indication. Figures 1 and 2 compare measured roadway surface temperature with the trends calculated from the measured values of the last 10 and 60 minutes in each case. The illustrations also show the radiation balance as an essential influencing parameter on roadway surface temperature.

Figure 1 shows a uniform progression of the roadway surface temperature which does not fluctuate in the short term on a largely cloudless day in January. The trend calculations correspond well to the actual values in the case of constant changes over a larger time span but, if major changes do occur, necessarily lead to differing results, primarily at sunrise or when the sun starts to go down.

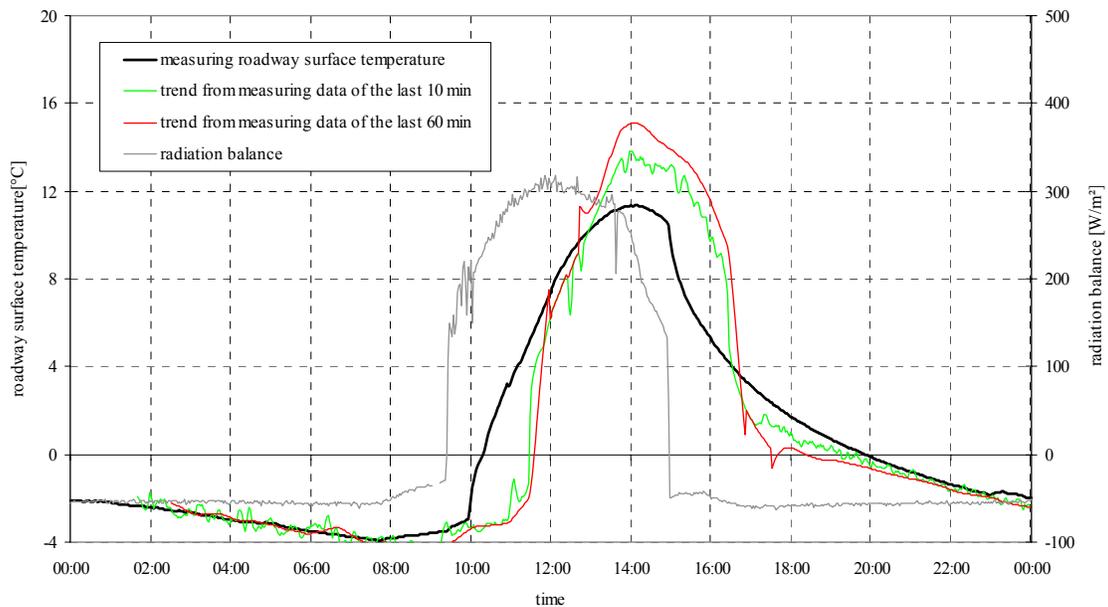


Figure 1: Actual and calculated roadway surface temperature progression over 24 hours on a largely cloudless day (mid-January)

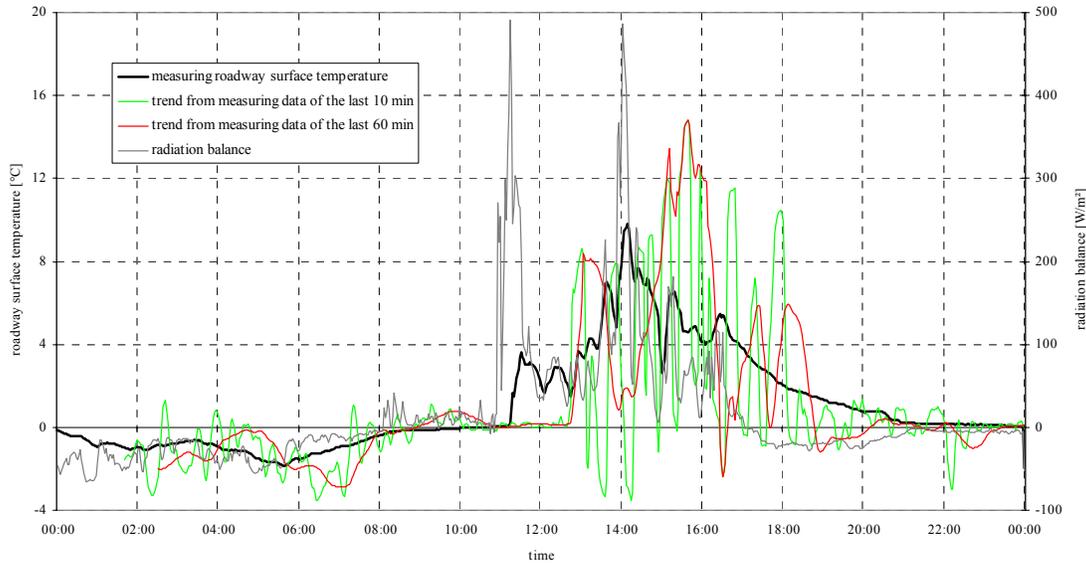


Figure 2: Actual and calculated roadway surface temperature progression over 24 hours on a day subject to changing cloud cover (early March)

Figure 2 shows a constantly changing progression of the roadway surface temperature during the daytime owing to changing cloud cover. Both the trend calculations with measured values of the last 10 minutes and the trend calculations with measured values of the last 60 minutes lead to differing results by comparison with the actual roadway surface temperatures which occurred.

As of a roadway surface temperature below $+2\text{ }^{\circ}\text{C}$, the model issues a skid-hazard warning with acute risk of skid hazard (skid hazard may occur immediately). This is intended to preclude possible measuring errors as a cause of an incorrect warning. The threshold value of $2\text{ }^{\circ}\text{C}$ may also be 0 or $+1\text{ }^{\circ}\text{C}$, depending on the accuracy of the measurement or the local situation.

The warnings also differentiate on the basis of the manner of formation of skid-hazard conditions by including the roadway condition (dry - moist - wet) and the dew point temperature. If the indication is “dry”, a warning of freezing rain or skid hazard owing to snowfall is issued at a roadway surface temperature below $+2\text{ }^{\circ}\text{C}$ or if the trend result is equal to or less than $0\text{ }^{\circ}\text{C}$. In addition, the air temperature is included since cold air may produce undercooled precipitation which may quickly lead to skid-hazard conditions. If the dew point temperature increases in the trend calculation or if the roadway surface temperature increases with the actual value already, a warning of roadway frost is also issued.

A warning of black ice is issued if the roadway condition is “moist” or “wet”.

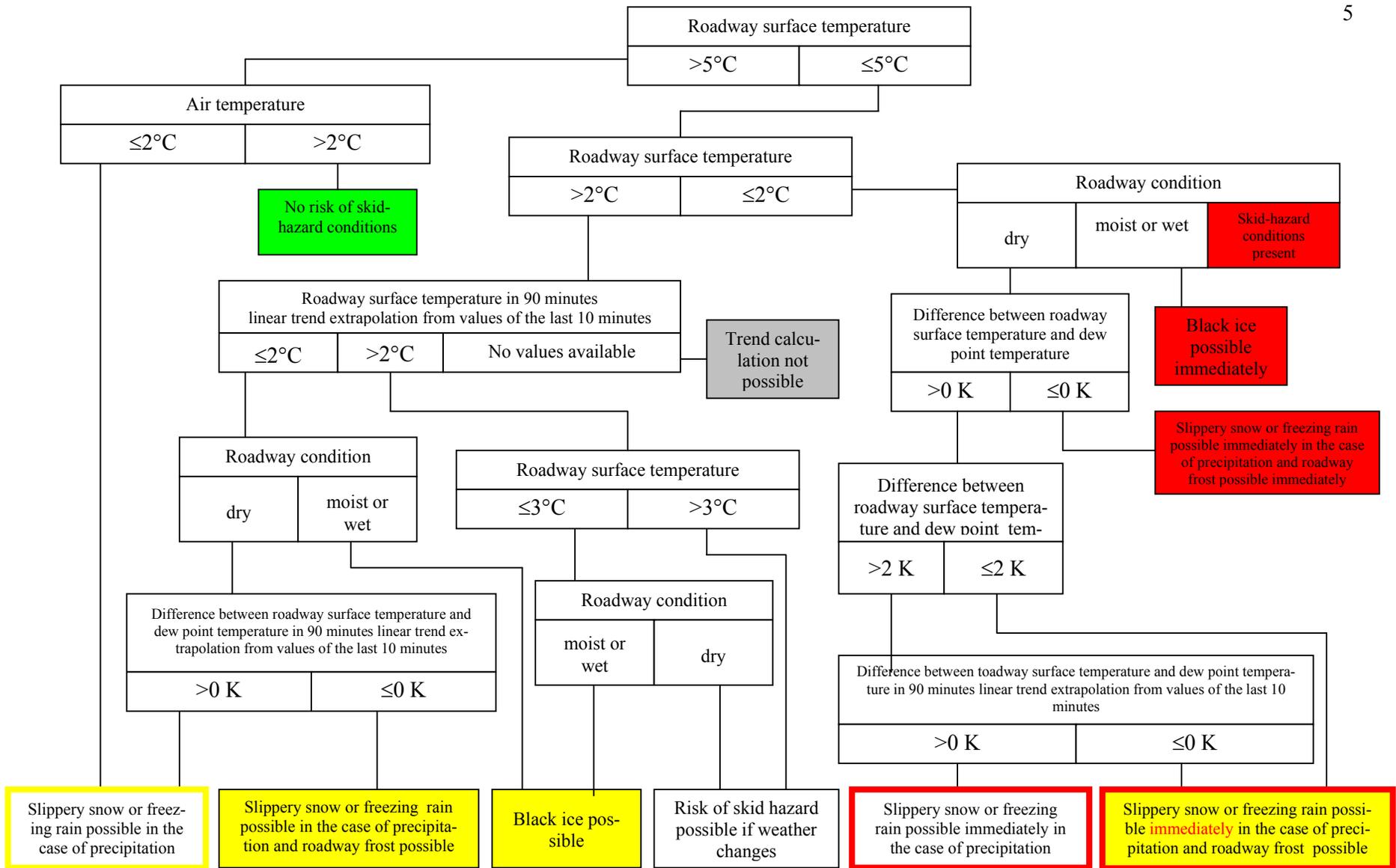


Figure 3: Skid-hazard warning model on the basis of road weather systems

Owing to the low plausibility of the results of sensors of various manufacturers which have been investigated, the model does not allow for salt which has been spread on the roadway and which leads to a lowering of the freezing temperature of existing moisture. The freezing temperature can, however, be integrated at any time in the model if the measured values are plausible.

2.3 Information on use

One very important aspect in relation to evaluation of the skid-hazard warning issued by models is that the underlying measured values describe only one single point for a stretch of road being monitored and that a different roadway surface temperature may occur even right next to it. A road weather system alone is unable to record the situation at other points in the network. Substantial differences in the roadway surface temperature between two stretches of road close by occur even in the case of differing cloud cover or shading. This is why a knowledge of the behaviour of the surrounding stretches of road in various weather stations is of major importance as regards evaluation of the information provided by the model in respect of dispatching a winter maintenance call-out. The person responsible for winter maintenance must decide, on the basis of situation (measured roadway surface temperature and precipitation), whether a call-out is required. He must also include in his decisions winter maintenance call-outs which have already occurred, owing to the fact that freezing temperatures are not allowed for in the model. It is not possible to make generally valid recommendations since no precise findings are available as to how long a quantity of salt spread on the roadway surface is still present after the action of traffic or precipitation.

Figure 4 shows a possible display of measurement data in an area to be monitored.

	Oberaudorf	Kiefersfelden	Dettendorf direction Salzburg	Dettendorf direction Munich	Autobahn- dreieck Rosenheim	Innbrücke Rosenheim	Prienbrücke direction Salzburg	Prienbrücke direction Munich	Bernauer Berg
roadway surface condition	2,6	2,2	1,0	2,6	3,5	-1,6	6,0	-2,5	1,5
roadway condition	moist	dry	dry	dry	moist	wet	wet	slippery	dry
frizing point	-3,3	no measuring possible	no measuring possible	no measuring possible	-5,5	-15,0	-3,0	-1,5	0,0
air temperature	2,0	1,0	2,5	3,0	5,0	-1,0	5,0	-1,0	2,0
relative humidity	86	99	95	87	75	98	97	99	58
dew point temperatur	-0,1	1,1	1,8	-0,2	4,0	-1,2	-2,8	-1,5	-3,0
precipitation	no precipitation	no precipitation	no precipitation	no precipitation	rain	snowfall	rain	snowfall	no precipitation
Skid-hazard warning on the dates of last 10 minutes	Black ice possible	Slippery snow or freezing rain possible in the case of precipita- tion and roadway frost possible	Slippery snow or freezing rain possi- ble immediately in the case of precipitation and road-way frost possible immediately	Slippery snow or freezing rain possible in the case of precipitation	Risk of skid hazard possible if weather changes	Black ice possible	no risk of skid hazard	Black ice possible	Slippery snow or freezing rain possible in the case of precipitation

Figure 4: Specimen monitor display for the measuring points in a monitoring area

It is necessary to use other sources of information on the current weather situation and its development for an estimation of the risk of skid hazard resulting from weather changes, e.g.:

- The measured values of the surrounding measuring points
- Precipitation radar images
- Satellite weather information (linking satellite images to ground measurement results)
- Forecasts within the framework of the SWIS Road Condition and Weather Information System of the German Meteorological Office or systems of other providers
- Weather warnings from meteorological services
- Third-party information (the police, motorists phoning to warn of traffic jams, breakdown services and neighbouring highway surveillance centres etc.)

It is possible to estimate more reliably how the roadway conditions and the weather will develop only by using as much of this information as possible. If, for instance, the satellite weather information indicates no cloud formations, it is not necessary for call-outs to be dispatched at roadway surface temperatures below 0 °C and if the air is dry. On the other hand, precipitation radar images or the measuring points of neighbouring stretches of road may indicate an approaching weather front even though no precipitation which could lead to a skid hazard is yet falling in the area being monitored.

A plausibility check of the model developed by the Federal Highway Research Institute with real data from various measuring points has indicated that it provides correct reports with reference to the anticipated type of skid hazard. The early warning times prior to a reported case of skid hazard were, in some cases, very long owing to the primary decision with the roadway surface temperature above/below +5 °C. However, extremely short time spans (< 10 minutes) until a reported, immediately possible case of skid hazard also occurred in very few cases. In such cases, undercooled precipitation had fallen on a roadway surface whose temperature dropped by almost 5 Kelvin within a few minutes owing to this event.

Consequently, users of the model are advised, at all times, to watch out for up-to-date information on weather changes which road weather systems are unable to indicate.

3 De-icing agent spray systems

Ambient and roadway condition data is still used by meteorological services for control of de-icing agent spray systems. De-icing agent spray systems are systems used by stationary winter maintenance intended to complement the snow clearance and de-icing agent application call-outs of the highway maintenance authorities. These systems make winter accident black-spots far safer and avoid traffic obstructions. Black ice which occurs suddenly can be effectively countered and the snow in the case of sudden, violent snowfall can be kept clearable by the

use of a de-icing agent spray system until the clearance vehicles arrive, thus allowing slippery snow to be avoided.

De-icing agent spray systems make a contribution towards speeding up winter maintenance overall in extreme weather conditions, which keeps traffic flowing more easily by avoidance of queues and traffic jams and helps to reduce overall economic loss. Operational savings can be achieved by dispensing with preventive winter maintenance call-outs, additional monitoring trips and also by staff not having to remain on standby at stretches of road subject to the risk of skid hazard.

Operation of a de-icing agent spray system is largely tripped automatically but can also be tripped manually. Incipient skid hazards are detected by a computer-aided road weather system, which by measuring the roadway condition and ambient data, trips a spraying operation if the risk of skid hazard is acute. Both data from conventional ground sensors for determining roadway surface temperature and freezing temperature and roadway humidity and meteorological sensors for air temperature, precipitation and relative humidity are included in this.

4 Summary

Road weather systems represent an indispensable element for winter maintenance control on federal highways in Germany, despite certain imponderables described. The measured data which they are used to obtain provides a far better knowledge of the roadway condition and weather parameters in the road network. In turn, this allows preventive measures to protect against the occurrence of skid hazards to be taken in targeted manner, thus making an essential contribution towards maintaining traffic and road safety and traffic flow on the most densely used roads.

The measured results of the sensors directly trip the operation of de-icing agent spray systems at stretches of road which are particularly subject to the risk of skid hazard.

One other advantage of the improved state of knowledge is the fact that it allows more accurate deployment of human resources in relation to scope and time of winter maintenance. In general, the resultant, targeted call-out saves substantial human resources costs.