Field Test of Road Weather Information Systems and Improvement of Winter Road Maintenance in Hokkaido

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After the studded tire regulation law came into effect, extremely slippery frozen road surfaces occurred in the Sapporo area. The Hokkaido Development Bureau (HDB) has been conducting Hokkaido-wide surveys of road surface conditions with other road administrators since February 1993. The purpose of the surveys is to determine frozen road surface occurrence and regional road surface conditions in Hokkaido. In addition, in the winter of 1993–1994, HDB introduced the Finnish ice prediction systems to downtown Sapporo. HDB examined the accuracy of the system and clarified its limits of application. It was confirmed that the system has some limits because of errors in detection, which frequently occurred in cases of much snow, compacted snow, and frozen road surfaces. In the winter of 1994–1995, a new road surface classification method, which can identify extremely slippery frozen road surfaces and is easily used in winter maintenance operation, was developed. The Hokkaido-wide winter road surface condition survey was conducted with the use of the new classification method. In addition, an investigation was begun to develop ice prediction methods by using the road weather information system (RWIS) for the greater Sapporo area in the winter of 1995–1996. In this investigation, use of the radar snowfall forecasting system was also considered, as was the use of forecast information for efficient winter road maintenance. Furthermore, the ideal RWIS of the next generation and the way to exchange and share the information with other organizations are now under discussion.

Since the winter of 1992–1993, when the studded tire regulation law came into effect, very slippery frozen road surfaces have occurred in the Sapporo area. The Hokkaido Development Bureau (HDB), with other road administrators, has been conducting Hokkaido-wide surveys of road surface conditions since February 1993. The purpose of the surveys is to examine frozen road surface occurrence and to establish countermeasures against it. Because the original road surface classification used in the survey was not sufficient to identify very slippery frozen road surfaces, a new, improved classification system was introduced.

Furthermore, HDB has introduced the use of Vaisala's ice prediction system in downtown Sapporo and examined the accuracy of the system since the winter of 1993–1994. Through the surveys over two winters, points for improvement were confirmed. On the basis of the results, investigations to develop new road condition forecasting methods for the greater Sapporo area have been conducted since the winter of 1995–1996.

Surveys of Road Surface Conditions

New Road Surface Classification

Snow plowing is the main method of winter road maintenance in Japan. No standards of winter road maintenance consider slipperiness. Formerly used road surface classifications were insufficient to suitably identify the very slippery frozen road surfaces that began to appear after the studded tire regulation law came into effect. In the meantime, Akitaya and Yamada (*1*) reported a classification method for snow and ice on roads from the viewpoint of snow scientists. By using their classification methods, it is possible to judge road surface slipperiness by appearance. Their method was improved and a new road surface classification method, which can identify the very slippery frozen road surfaces described, was suggested (Figure 1).

The new road surface classification method was based on "road surface condition," which describes the characteristics of snow and ice on roads, and snow deposit shape, which describes the shapes of snow and ice deposits. Road surface condition consists of "reflection on the surface," "snow property," and "latent slippery ice under the surface," and the "snow deposit shape" consists of "Bump" and "rutting." Terms in this new road surface classification method are as follows:

1. Slipperiness is judged by reflection on the road surface. In cases in which the surface reflects sunlight or a headlight beam well, "very slippery" precedes snow property.
2. Snow property is classified into "compacted snow," "ice crust," "ice film," "slush," "powder snow," and "grain snow." A flow chart allows easy assessment of snow property (Figure 2).
3. If a slippery ice is covered with powder or grain snow, "on ice" follows snow property. In this situation, the subsurface ice has a much greater effect on vehicles than does the powder or grain snow on the surface, and it is important to discriminate between this situation and another.
4. A bump is described by size. Observed bumps less than 5 cm high are called "small bump," and those 5 cm or more are called "big bump."
5. Rutting is described by depth. Rutting less than 5 cm deep is called "shallow rutting," and that 5 cm or deeper is called "deep rutting."
6. Dry and wet (bare pavement) are considered types of road surface conditions.

With this new classification method, 13 states of road surface condition may be described.

Analysis of Survey

HDB surveyed road surface conditions using the new classification system at 41 locations in Hokkaido starting in December 1994. Snowplowing and the spreading of deicing agents and abrasives were also considered in the survey.

Figure 3 presents the relationship between days of snow removal and days of spreading of deicing agents and abrasives. Figure 3 shows that spreading of deicing agents and abrasives was as popular as snowplowing at some locations (Group A), whereas mainly snowplowing was conducted at others (Group B). Table 1 shows that the ratio of very slippery road conditions in Group B was higher than that in Group A. This indicates that deicing agents and abrasives are becoming more important as winter road maintenance methods under the studded tire regulation law.

INSPECTIONS FOR ICE PREDICTION SYSTEM

Introduction of Ice Prediction Systems

HDB has used Vaisala's Icecast system in downtown Sapporo since the winter of 1993–1994 and has examined the accuracy of the system and clarified its limits of application.

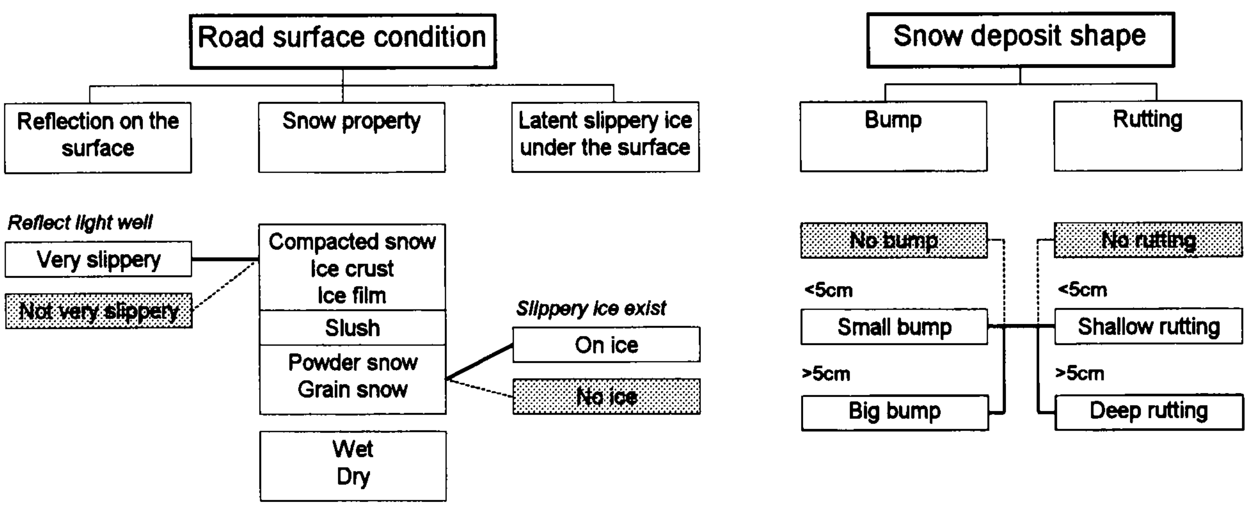

FIGURE 1 New classification method (shaded words are not classification terms).

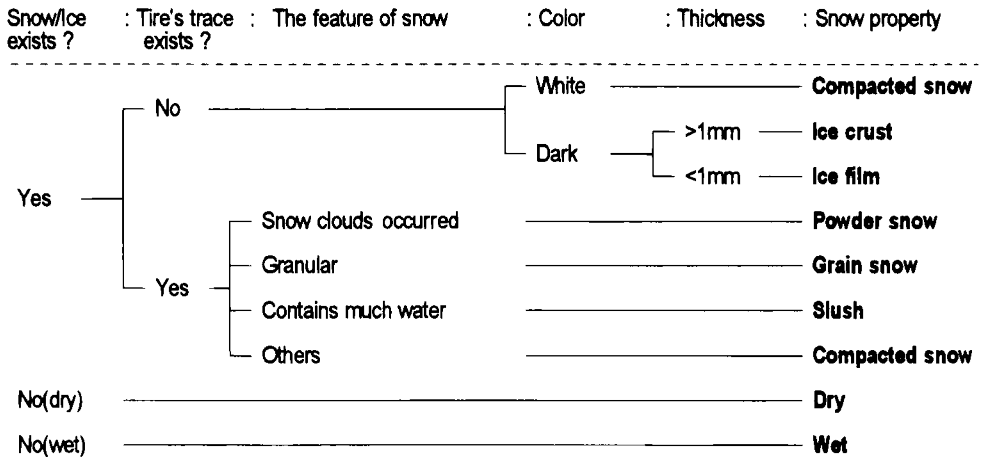

FIGURE 2 Flow chart of "snow property" decision.

Weather observation stations were installed at sites in two environments. Site 1 was surrounded by buildings and Site 2 had only one tall building, to the southeast. Air temperature, relative humidity, road surface temperature, and rainfall were measured by the original sensors. In addition, the amount of precipitation was measured by a precipitation gauge and road conditions were observed and recorded by video camera.

Road Sensor Inspection

The road sensor DRS12 (Vaisala) can measure road surface conditions, remaining chemicals, road surface temperatures, and ground temperatures. The sensors describe eight types of road surface conditions. The conditions obtained by the sensor were compared with a video camera's observations classified into four types: dry, wet, snow, and ice (Figure 4). The correspondence ratio was defined as the number of cases in a given shadowed area divided by the total number of cases recorded.

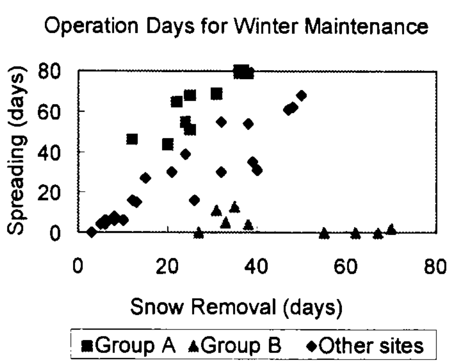

FIGURE 3 Comparison of days with salt or sand spreading and those with snow removal.

Table 2 shows the average correspondence ratio of each month in the winters of 1993–1994 and 1994–1995. The average correspondence ratio was 50 to 60 percent, but was lower in January and higher in March. These inconsistencies were then investigated. Table 3 shows the results of the investigation conducted at Site 1 during the winter of 1994–1995. The investigation showed that 48 percent of ice, 28 percent of wet, and 23 percent of snow indicates treatment by the sensor. Site 2 showed the same tendency.

Accuracy of Ice Prediction System

To forecast road conditions by using the Icecast model, weather forecast data (air temperature, dew point, cloud amount, cloud type, and precipitation) were

TABLE 1 Ratio of "Very Slippery Road" Appearance

Group A		Group B	
Site	Ratio (%)	Site	Ratio (%)
A-1	2.5	B-1	35.5
A-2	3.3	B-2*	0.8
A-3	12.4	B-3	14.0
A-4	9.9	B-4	9.1
A-5	0.0	B-5	38.8
A-6	2.5	B-6	14.9
A-7	5.0	B-7	22.3
A-8	5.8	B-8	21.5
A-9	5.0	B-9	33.9
A-10	5.0		
A-11	9.9		
A-12	0.0		
Average	5.1	Average	21.2
		(except B-2)	31.2

(* Use of studded tire was admitted around site B-2)

DRS12's Indication			Video's observation			
Symbol	Meaning	Road conditions	Dry	Wet	Snow	Ice
DR	Dry	Road surface is dry				
TR	Treatment	There is salt on the road surface and dry				
WE	Wet	There is free water on the surface				
WT	Wet/Treatment	There is salty free water on the surface				
MO	Moist	There is moisture on the surface				
FR	Frost	Frost is forming				
SN	Snow	There is snow or white ice on the surface				
IC	Ice	There is transparent ice on the surface				

FIGURE 4 Matrix of correspondence between DRS12 indication and video observation.

entered as meteorological parameters for the system. To confirm the accuracy of the model, the retrospective verification results obtained from actual measured data were compared with the video observations. Table 4 shows that the correspondence ratio at both sites was approximately 60 percent. The accuracy of the forecasting meteorological parameters is increasing, but improvements in road condition predictions are limited. It is impossible to explain the reason because the algorithm of the model has not been revealed, but ignoring snowfall depth as a meteorological parameter may be unwise.

Suggestions for Improvement

Suggestions for improvement of the ice prediction systems are as follows.

1. Because there are many errors in the treatment indications by the road surface sensor, another method is needed to obtain actual road conditions.
2. Snowfall depth must be considered in road condition predictions.
3. Whether ice forms on roads is sufficient for winter road maintenance in a country with a "bare pavement" policy. Snow and ice often are found on roads because of the heavy snow in Japan. Therefore, the ice prediction system must account for the formation of very slippery roads in winter road maintenance.

TABLE 2 Ratio of DRS12 Indication Considered Same as Video Observation (Percentage)

	Site 1		Site 2	
	1993/94	1994/95	1993/94	1994/95
DEC.		56.0		51.2
JAN.	29.2	52.2	30.2	50.9
FEB.	52.3	51.8	46.7	66.7
MAR.	66.4	77.7	70.8	80.7
AVE.	49.8	59.6	51.0	62.2

Development and Investigation of New Prediction System

Investigations into Ice Prediction

Investigations to develop new ice prediction methods for the greater Sapporo area were begun in the winter of 1995–1996. The meteorological office was responsible

TABLE 3 Comparison of DRS12 Indication and Video Observation at Site 1

	Video's Observation				
DRS12's Indication	Dry	Wet	Snow	Ice	Total
DR	1031	145	35	35	1246
TR	147	448	221	738	1554
WE	61	547	28	12	648
WT	0	159	9	8	176
MO	187	62	8	2	259
FR	0	7	11	11	29
SN	23	232	613	686	1554
IC	21	13	23	45	102
Total	1470	1613	948	1537	5568

NOTE: DR = Dry, TR = Treatment, WE = Wet, WT = Wet/Treatment, MO = Moist, FR = Frost, SN = Snow, IC = Ice.

TABLE 4 Ratio of Predicted to Observed Forecast Data (Percentage)

Time	18	21	00	03	06	09	11	Average
Site 1	54.2	59.4	61.7	61.7	64.5	63.6	55.1	60.0
Site 2	56.1	66.4	72.0	70.1	67.3	57.0	56.1	63.6

for investigation of ice prediction. Two stretches of highway, from Sapporo-Miyanosawa to Otaru-Irifune on National Route 5 (Route A), and from Sapporo-Toyohira to Sapporo-Kiyota on National Route 36 (Route B), were chosen for study, and representative points on those highways were selected. The ice prediction period was from December 24, 1995, to February 17, 1996. By 18:00 every evening the meteorological office predicted road conditions for 0:00 and 8:00 the next day. The predictions were sent by fax at 18:00 to the Civil Engineering Research Institute, Sapporo Road Office, and winter road maintenance operator's offices. Thirteen types of road surface condition in the new classification method were used in these predictions of road conditions.

The winter road operator's office is responsible for making observations of road conditions and maintaining records of winter road operations. Observations of road conditions were conducted at the representative points every day at 0:00, 8:00, and 16:00. The results were reported by fax to the meteorological office by 17:00. Road conditions at 16:00 were used in the predictions, and conditions at 0:00 and 8:00 provided data for the later investigations of the accuracy of the predictions. In addition, the records of winter road operation were also reported to the meteorological office along with the faxed information on road observations. These results were used later when the accuracy of the prediction system was examined (Figure 5).

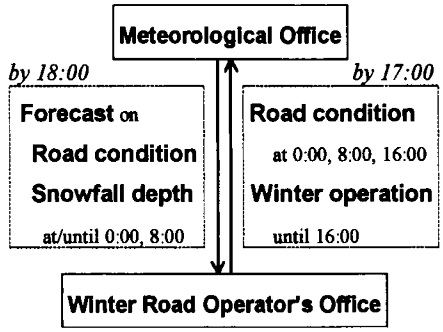

FIGURE 5 Flow of information.

Results of Predictions

Actual measured data or road and weather conditions were analyzed, and flow charts on road conditions were developed (Figure 6).

The prediction points along Routes A and B were referred to as Sites A1 through A5 and Sites B1 through B4, respectively. Table 5 shows the ratio of correspondence between the predictions and observed road conditions at each site, based on 13 types of road surface condition. Table 5 clearly shows that this prediction method has yet to reach a practicable stage of development.

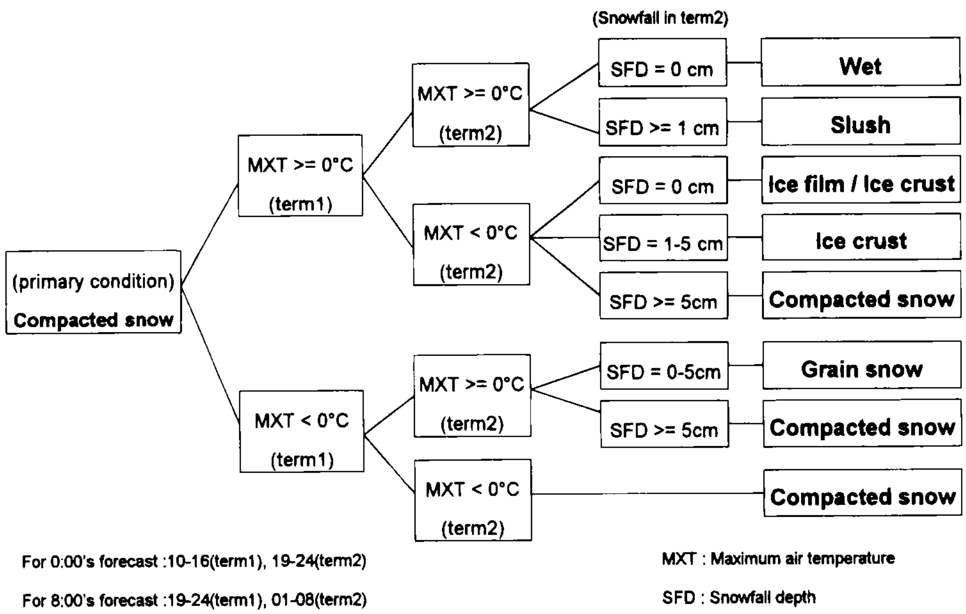

FIGURE 6 Example of forecast flow chart.

TABLE 5 Ratio of Predicted to Observed Forecast Data

	Time			Time	
Sites	0:00	8:00	Sites	0:00	8:00
Site A1	0.35	0.29	Site B1	0.28	0.14
Site A2	0.32	0.32	Site B2	0.26	0.16
Site A3	0.32	0.31	Site B3	0.26	0.16
Site A4	0.20	0.21	Site B4	0.25	0.19
Site A5	0.27	0.36			

CONCLUSIONS

The introduction of the European ice prediction system to Japan has had some problems because of the amount of snowfall in Japan and the differences in winter maintenance levels. However, developing an ice prediction method for snowy areas that is unique to Japan also is not easy. Nevertheless, improvement in winter road maintenance is expected of road administrators and is a subject that cannot be avoided. In addition to conducting the surveys, HDB has conducted improvements of the snowfall forecast system through the integrated use of other administrations' weather radars, and an analysis of the cost and benefit of ice predictions. Furthermore, a working group consisting of concerned representatives has met and discussed ways to exchange and share information with other organizations and the ideal RWIS for the next generation. Through these surveys, winter road maintenance will be improved.

REFERENCES

1. Akitaya, E., and T. Yamada. Classification of Snow and Ice on Roads (in Japanese). *Proc., Cold Region Technology Conference*, 1994, pp. 63–69.