WINTER ROAD MANAGEMENT STANDARDS OF THE HOKKAIDO DEVELOPMENT BUREAU

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Introduction

In cold, snowy regions, the efficiency of roads are decreased, because in winter as a result of various factors such as snowfall, snow cover, and icy road surfaces. The road administrator in these area, must remove snow, spread anti-freezing agents, and conduct other operations. Hokkaido, the northernmost prefecture in Japan, is confronted by the most severe conditions in the nation for winter road management and maintenance because of freezing temperatures and heavy snowfall. The Hokkaido Development Bureau bears the responsibility under these severe conditions of administrating the prefecture's national highways, which form the backbone of Hokkaido's road network. This paper outlines the current situation of winter road management by the Bureau today, as well as future issues that it must address.

1. Climate of Hokkaido

Japan, a long and slender archipelago, extends a great distance north-south. Not surprisingly, Hokkaido, its northernmost island, represents the nation's coldest region. The mean temperature for January throughout the whole prefecture lies below freezing[1)]. With a climate characterized by heavy snowfall and cold (Figure 1), the island faces the harshest conditions for road management and maintenance in the nation.

Data from the Automated Meteorological Data Acquisition System (AMeDAS) show that the region's daily mean temperature in January varies substantially from one area to another, the highest being -0.5 degree in Kumaishi and the lowest being -8.1 degree in Rikubetsu. Coastal areas bordering the Pacific have little snowfall, whereas the remaining areas have heavy snowfall.

2. Snow Removal Operations by the Hokkaido Development Bureau[2)]

The Bureau's snow removal operations cover almost the total length (99.6% of 6,243 km) of the national highways managed by the Bureau (as of FY 2000)[7)]. Its ten regional Development and Construction Departments are in charge of their respective jurisdictions, with the snow removal operations undertaken by their 49 depots throughout Hokkaido.

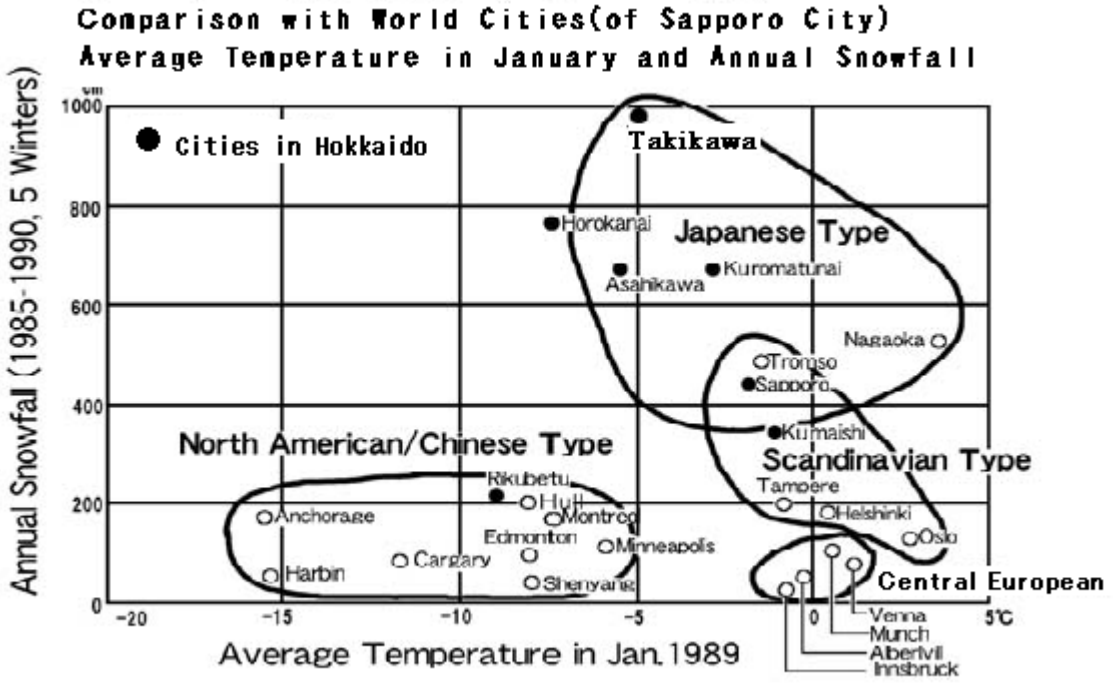

Figure 1 Average Temperature in January and Annual Snowfall of Each City [1)]

The current snow removal standards define three target levels, with each route classified according to its degree of importance and traffic volume.

Snow removal operations are either high-speed or low-speed, depending on the operating speed of the snowplow. Snow removal operations are further divided according to time and purpose into newly fallen snow removal, surface leveling, snow hauling and disposal, auxiliary operations, ice prevention and the removal of snow from shoulders to widen the usable road surface.

While mainly snowplows carry out these snow removal operations, snow disposal also involves the use of ancillary road structures, including snow-flowing gutters, road heating systems, and automatic anti-freezing chemical spreaders. However, no snow-melting water sprinklers are used in Hokkaido because winters are too cold.

Winter road surface management requires anti-freezing agents and abrasives. The main anti-freezing agent is a sodium chloride-based mixture. Sea salt, the sodium chloride produced domestically, tends to clump together at low temperatures and thus has low workability. Mixing sea salt with calcium chloride and magnesium chloride maximizes its workability. The primary abrasive is sand of relatively small grain size, dehydrated via heating.

3. Emergence of Typical Winter Road Conditions and the Causes

Matsuzawa, et al. reported the emergence rates of winter road conditions[4)]. In this study the emergence of typical snowy/icy road conditions on national highways was surveyed near AMeDAS observation stations throughout Hokkaido to identify specific weather conditions that contributed to the emergence of snowy, icy roads.

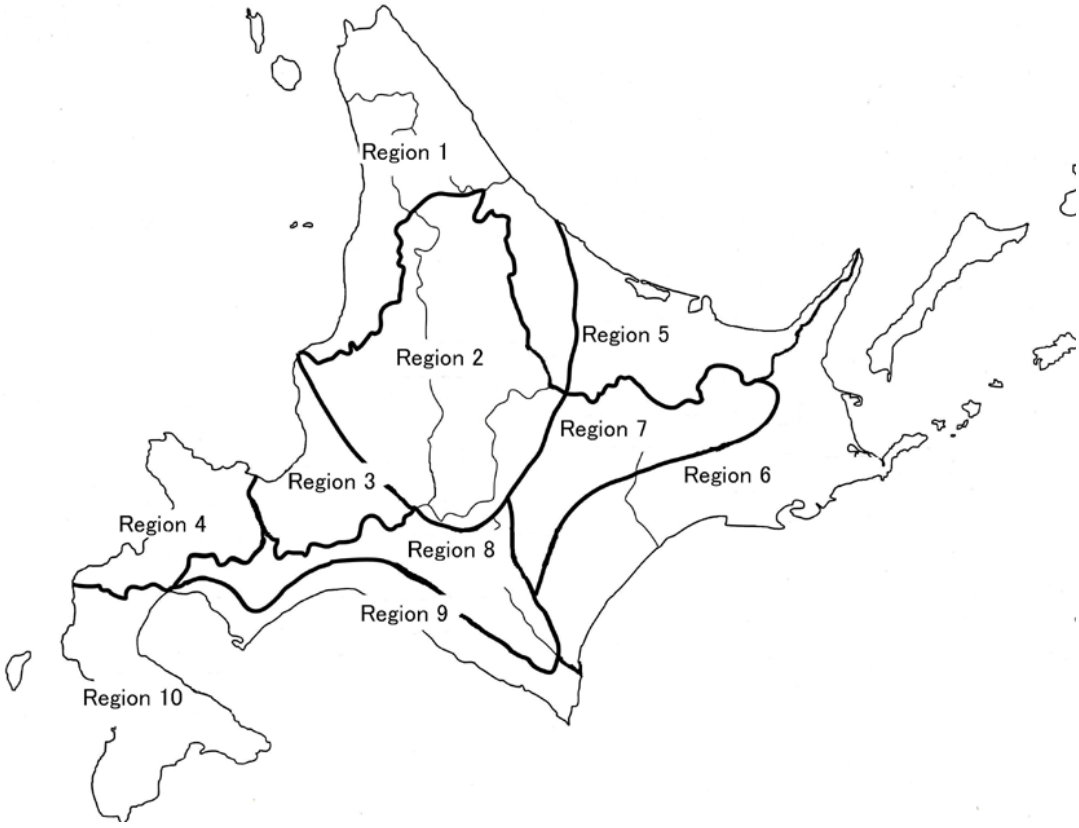

Figure 2 Division of Regions by the Emergence Rate of Typical Winter Road Conditions

In the survey, (Figure 2) based on the 6-year emergence rates of typical road conditions during the winter (December - March). Hokkaido- wide, the emergence rate of typical snowy/icy road conditions including slush, compacted snow, and ice layer on top of snow/ice road stands at approximately 60%.

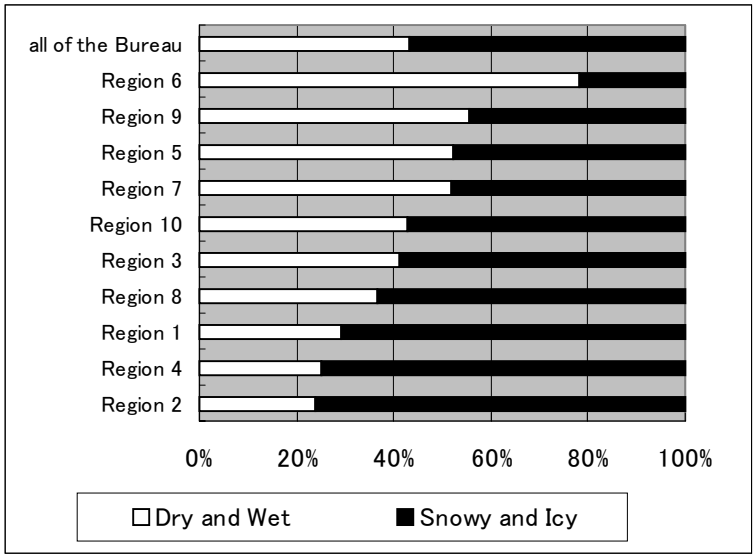

Figure 3 Ten regions and their Respective 6-year Emergence Rates of Winter Road

In Region 6, the emergence rate of dry/wet road conditions was 80%, while regions 1, 2, 4, on the contrast, had an approximate 80% emergence rate of snowy and icy road conditions. This contrast highlights the fact that road management strategy should not be uniform throughout Hokkaido but should take into account regional characteristics.

Next, the weather conditions contributing to the emergence rate of winter road conditions conditions were identified using multiple regression analysis (Table 1). From among the Various AMeDAS meteorological data, five meteorological data factors shown via t-test to be Various independent were chosen as the independent variables. The analysis found that the emergence rates of both snowy/icy and dry/wet road conditions correlated most closely with the duration of sunshine,

followed by mean temperature. The other meteorological factors were found to have extremely low correlations, a result which means that dry/wet and snowy/icy road conditions depend almost entirely on the sunshine duration (insulation) and air temperature.

The analysis did not consider the differences in snow removal standards, the spreading of anti-freezing agents, or other key factors. However, it did show that the way the remaining snow on the road is melted (either by solar radiation or heating) strongly influences the conditions of roads treated with mechanical snow removal.

Table 1 Multiple Regression Analysis of Correlation Between the weather Conditions and the Emergence Rates of Typical Winter Road Surfaces

	Dry/wet road surface			Snowy/icy road surface		
Variable	Partial regression coefficient	Standard partial regression coefficient	Partial correlation	Partial regression coefficient	Standard partial regression coefficient	Partial correlation
Average temperature	0.0456	0.3766	0.5915	-0.0456	-0.3766	-0.5915
Average wind velocity	-0.0321	-0.1374	-0.2852	0.0321	0.1374	0.2852
Duration of sunshine	0.0012	0.7613	0.7576	-0.0012	-0.7613	-0.7576
Precipitation	-0.0002	-0.1106	-0.1996	0.0002	0.1106	0.1196
No. of snow days	-0.0035	-0.1385	-0.2535	0.0035	0.1385	0.2535
	Equation for multiple regression analysis					
Dry/wet road surface	Y1=0.0456X1-0.0321X2+0.0012X3-0.0002X4-0.0035X5+0.7004					
Snowy/icy road surface	Y2=-0.0456X1+0.0321X2-0.0012X3+0.0002X4+0.0035X5+0.2996					

Y1: Emergence rates of dry/wet road surfaces Y2: Emergence rates of snowy/icy road surfaces

X1: Average temperature X2: Average wind velocity X3: Duration of sunshine

X4: Precipitation X5: No. of snow fall days

Adjusted coefficient of determination: 0.839 Adjusted multiple correlation coefficient: 0.916

4. Winter Road Management by the Hokkaido Development Bureau

The heavy snows in most of Hokkaido make snow removal essential. Since June 1990 when the Law on the Prevention of Generation of Particulates from Studded Tires went into effect, measures to address slippery snowy/icy road conditions have become have become as important as snow removal. Only a very small quantity of anti-freezing agents and abrasives were used in Hokkaido prior to the restriction on metal-pin studded tires. However, the quantity has increased substantially since the FY 1992 blanket ban on metal-pin studded tires (Figure 4).

Figure 5 shows the total volumes of anti-freezing agents and abrasives used in FY 1999 agents in each of the ten regions of Hokkaido categorized according to winter road conditions. Hokkaido-wide, the volume spread per kilometer of the total length of national highways managed by the Bureau was approximately 7 tons for anti-freezing agents and approximately 5 tons for abrasives. The volumes applied per kilometer varied widely by region, ranging from one ton to more than ten tons for anti-freezing agents, and from zero to over 20 tons for abrasives. Table 2 shows the correlation of total volumes of anti-freezing agents and abrasives used per kilometer of national highway to the AMeDAS meteorological data and the emergence rates of typical winter road conditions. As shown in table 2, very little, if any, correlation exists among these items. This absence suggests that the difference in the application volumes of anti-freezing agents and abrasives is due to the degree of importance of the route based on traffic volume, rather than to meteorological factors.

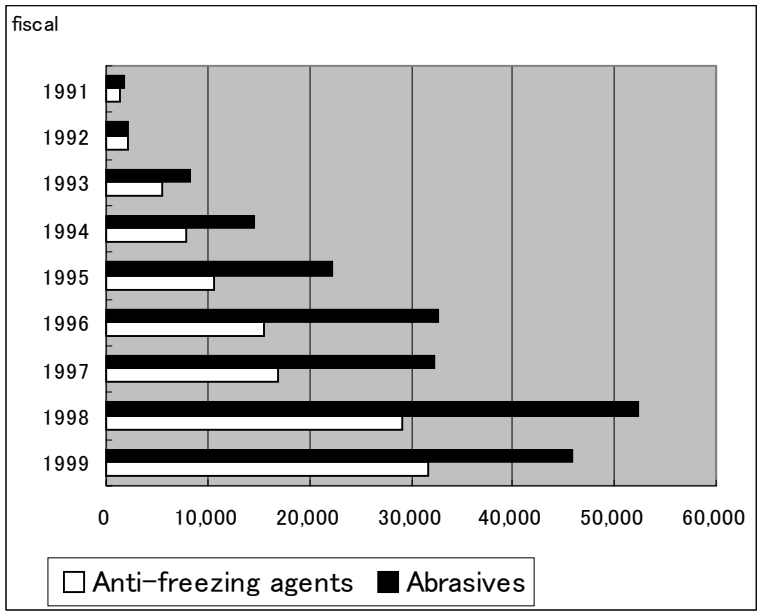

Figure 4 The Volumes of Anti-freezing and Abrasives Used in the Bureau

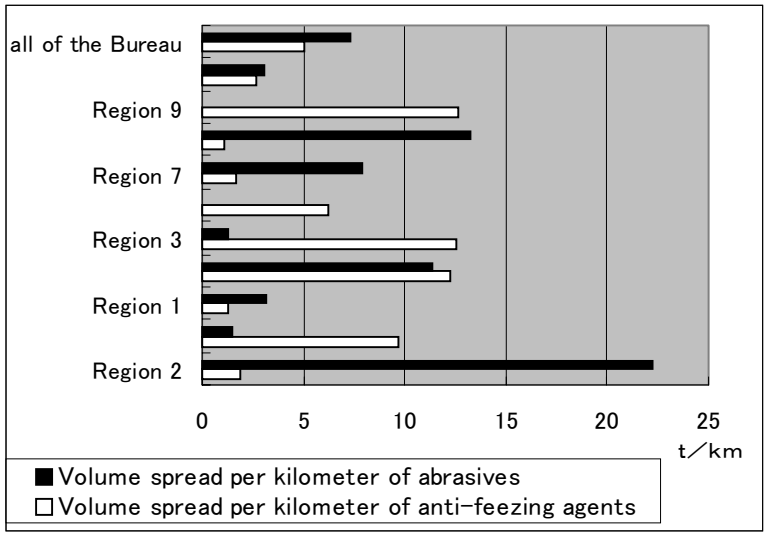

Figure 5 Volumes of Anti-freezing Agents and Abrasives Used per Kilometer by the Bureau

Figure 6 shows the ratios of anti-freezing agents to abrasives used in these regions. In Hokkaido, this ratio differs regionally.

Table 2 Spreading Rates of Agents per Kilometer of the Total Length of National Highways Managed by the Bureau

Correlation between the meteorological data and the emergence rates of winter road surfaces

	Anti-freezing agent	Abrasive
Average temperature (℃)	0.1425	-0.3099
Average wind velocity (m/s)	0.0386	-0.1981
Duration of sunshine (h)	-0.456	0.0028
Precipitation (mm)	0.2	0.1302
No. of snow days	0.2141	0.1204
Emergence rates of dry/wet road surfaces (%)	-0.3947	0.0079
Emergence rates of snowy/icy road surfaces (%)	0.3947	-0.0079

Also, comparison between Figures 6 and 3 suggests very little, if any, correlation between the ratios of agents and abrasives and the emergence rates of typical winter road conditions.

Using multiple regression analysis, the correlation between the ratio of agents and abrasives and meteorological factors were analyzed (Table 3). It is shown that agent/abrasive selection depended on the air temperature, with the other meteorological factors having very little, if any, impact on the choice. In regions with relatively higher temperature, anti-freezing agents were preferred in regions with relatively lower temperature, abrasives were preferred.

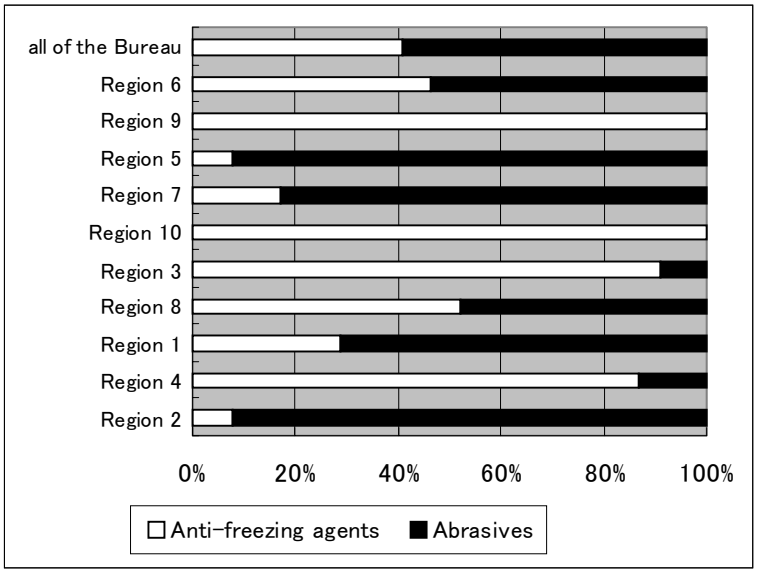

Figure 6 Ratios of Anti-freezing Agent to Abrasives Used in the Bureau

Table 3 Multiple Regression Analysis of Correlation Between the Weather Conditions and the Selection of Agents

	Anti-freezing agent			Abrasive		
Variable	Partial regression coefficient	Standard partial regression coefficient	Partial correlation	Partial regression coefficient	Standard partial regression coefficient	Partial correlation
Average temperature	0.1638	0.849	0.7048	-0.1638	-0.849	-0.7048
Average wind	-0.0363	-0.0982	-0.1267	0.0363	0.0982	-0.1267
Duration of sunshine	0.0004	0.1562	0.1416	-0.0004	0.1562	0.1416
No. of snow days	0.0041	0.1018	0.115	-0.0041	-0.1018	-0.115
	Equation for multiple regression analysis					
Anti-freezing agent	Y1=0.1638X1-0.0363X2+0.0004X3-0.0003X4-0.0041X5+0.6405					
Abrasive	Y2=-0.1638X1+0.0363X2-0.0004X3+0.0003X4+0.0041X5+0.3595					

Y1: Percentages of use of anti-freezing agent Y2: Percentages of use of abrasive
X1: Average temperature X2: Average wind velocity X3: Duration of sunshine X4: Precipitation X5: No. of snow fall days
Adjusted coefficient of determination: 0.5543 Adjusted multiple correlation coefficient: 0.7445

5. Future Issues and Proposal

This paper has outlined the winter road management currently implemented by the Bureau in relation to the climate of Hokkaido. Since the ban on metal-pin studded tires, measures for slippery winter roads have become a matter of special importance for the Bureau, and the volumes of anti-freezing agents and abrasives have been increasing significantly. Given this increase, the Bureau aimed to replace the practice of relying heavily on subjective opinions and experience with rational and systematic guidelines for the use of agents.

In opinion sand experience with rational and systematic guidelines for the use of agents. In FY 1997, the Winter Road Surface Management Manual was drafted toward this end. The manual (draft) proposes winter road management standards for uniform application throughout Hokkaido (Table 4) and standard application rates of anti- freezing agents (Table 5). As described in this paper, however, there are many different weather conditions in Hokkaido and such local characteristics require due consideration. Accordingly, the Bureau proposes a target level of services and methods for winter road management that take into account regional climatic differences. (The Bureau will make the utmost effort to achieve these targets but is not responsible to do so at all times.) The proposal is intended only as a basic guideline for the severest winter periods and allows for exceptions. For example, in early and late winter when usage rate of winter tires is low, roads for all of Hokkaido should be maintained so that vehicles equipped with summer tires can drive safely. Also, abnormal weather should be countered with appropriate measures for that particular weather condition.

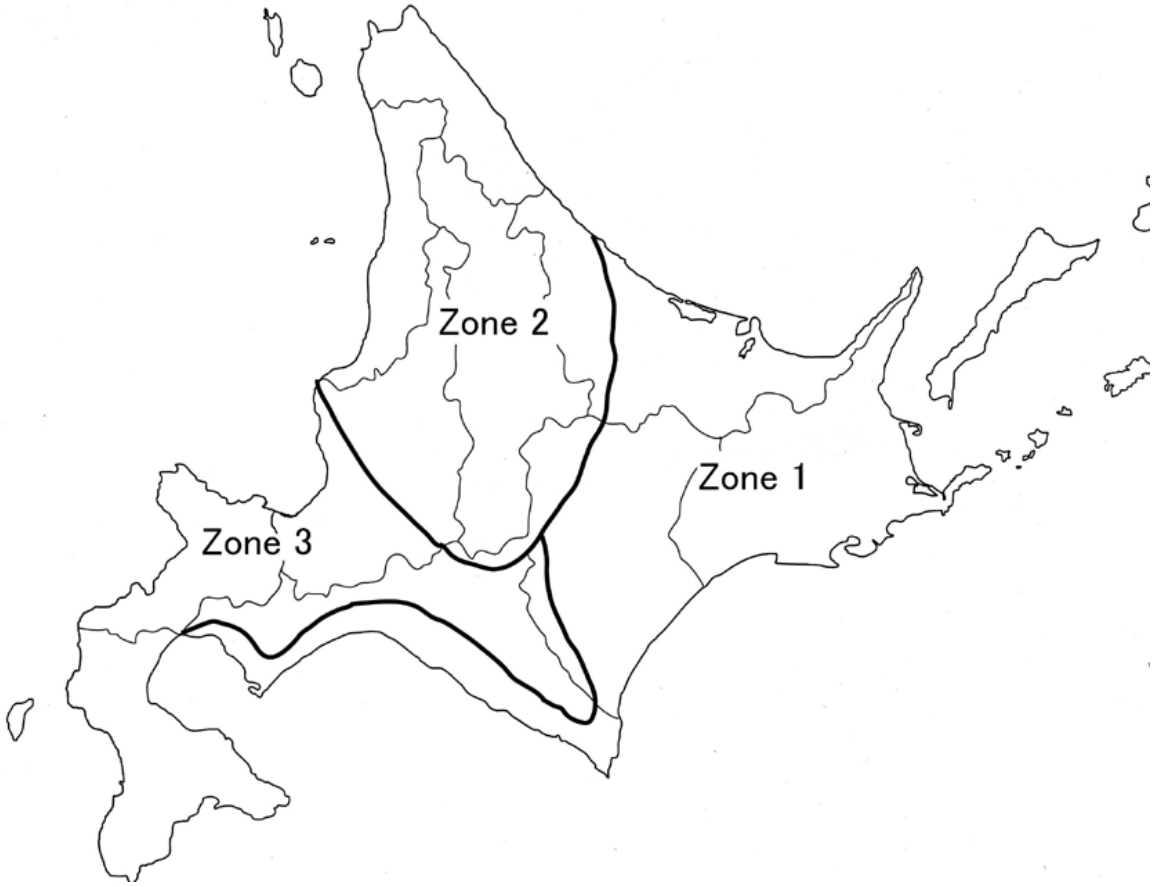

Figure 7 Three Zones for Winter Road Management (proposed)

5. 1 Zone 1

Zone 1 contains Regions 5, 6, 7 and 9. Except in some mountainous areas, Zone 1 is characterized by relatively longer sunshine periods and higher emergence rates of dry/wet road surfaces in winter. Zone 1 road surfaces that become wet in the daytime tend to freeze into black ice at night.

It is therefore important to apply agents to prevent nighttime freezing. In principle, abrasives will not be used. When snow and ice have accumulated substantially on roads, anti-freezing agents are spread after surface leveling so that subsequent solar radiation will render the road surfaces dry/wet.

5. 2 Zone 2

Zone 2 contains Regions 1 and 2. Relatively higher emergence rates of snowy and icy roads, lower temperatures, greater snowfall, and shorter periods of sunshine characterize Zone 2. Given these facts, achieving wet/dry road conditions by means of snow removal and anti-freezing agents is considerably difficult. Consequently, abrasives are mainly used to control slipperiness while anti-freezing agents are a supplementary measure. However, black ice needs to be treated by anti-freezing agents.

Table 4 Provisional Levels for Winter Road Surface Management

Application clazzification of management objectives

Road conditions / Daily traffic volume	Urban area	Flat area	Mountainous area
20,000 ～	A	B	B
10,000 ～ 20,000	B	C	B
4,000 ～ 10,000	C	D	C
1,000 ～ 4,000	D	D	D
～ 1,000	E	E	E

Notes :
1) For daily traffic volume, in principle, 24-hour traffic volume (in autumn) in the road traffic census is used
2) Road conditiona are classified based on the following conditions

Urban area
: urban areas with a series of intersections
Flat area
: flat lands other than urban areas
Mountainous area
: mountainous and piedmont areas, among other areas, which generally have disadvantageous slopes and alignments

Surface standard

Road surface standard	Classification of road surface
1	Extremely Slippery Thin Ice Extremely Slippery Thick Ice Extremely Slippery Compacted Snow
2	Thick Ice Powder Snow on Ice Crust Thin Ice
3	Granular Snow on Ice Crust Compacted Snow
4	Powder Snow Granular Snow Slush
5	Wet Dry

Management objectives

Management objectives	
A	Road surface standard 4 to be ensured 24 hours a day
B	Road surface standard 4 to be ensured between 6:00 to 22:00. In other time zones, road surface standard 3 to be ensured.
C	Road surface standard 3 to be ensured 24 hours a day
D	Road surface standard 3 to be ensured between 6:00 to 22:00. In other time zones, road surface standard 2 to be ensured.
E	In princiciple, road surface standard 2 to be ensured 24 hours a day. Appropriate response to snow removal and road traffic conditions to be promoted.

Table 5 Application Amount for Anti-freezing Agents and Abrasives

Classification	Spreading methods	Amount	Remarks
Anti-freezing agents	Wet spreading (or dry spreading)	30 g/m^2 15 g/m^2 * for anti-freezing, not for de-icing * when the snow depth is not so much	liquid amount for wet spreading is controled 10-30% of agents weight sodium chloride or calcium chloride liquid is used
	liquid spreading	50 ml/m^2 * for anti-freezing, not for de-icing * when the snow depth is not so much	Density of the liquid : sodium chloride 20-25% : calcium chloride about 30%
Abrasives	150 - 350 g/m^2		In wet spreading, sodium chloride or calcium chloride liquid is used

5. 3 Zone 3

Zone 3 contains Regions 3, 4, 8 and 10. Zone 3 is characterized by relatively higher emergence rates of typical snowy/icy road conditions, greater snowfall, and higher temperatures. Above all, Zone 3 typically has the highest emergence rates of very slippery road surfaces, requiring the closest possible attention to the road management.

Zone 3 has relatively shorter periods of sunshine but higher winter temperatures. The road surface conditions can be improved through the application of anti-freezing agents for a considerable number of winter days. Consequently, anti-freezing agents should be the primary means of road management, supplemented by abrasives when temperatures are low.

6. Conclusion

Since studded tires were banned, the Hokkaido Development Bureau has been striving to make winter road surfaces less slippery through various measures including the spreading of anti-freezing agents and abrasives. As a result, very slippery winter roads, which suddenly appeared after the metal-pin studded tire ban came into effect, saw a dramatic drop in emergence rates. On the other hand, the volumes of anti-freezing agents and abrasives used have drastically increased, causing road maintenance costs to rise and raising concerns about adverse impacts on the environment. It is therefore important to devise measures that produce maximum effects while using a minimum of anti-freezing agents and abrasives. Immediately after the studded tire ban, some people voiced concern that the improvement of studless tires and driving skills alone would not be sufficient to prevent traffic accidents[5]. In the ten years since then, the improvement of skidding coefficients of winter roads by anti-freezing agents and abrasives has been indispensable for the safe performance of studless tires. This effect is clearly indicated by the drastically increased use of anti-freezing agents and abrasives.

This paper has outlined the winter road management practices currently employed by the Bureau in relation to the climate of Hokkaido. Based on this examination, this paper proposes respective road maintenance programs that consider the local climate needs/conditions for each area of Hokkaido rather than a Hokkaido-wide program. To address the special weather conditions in Hokkaido, such as blowing snow on roads and radiative cooling whereby the temperature drops very low despite substantial insolation, specific road management methods and standards also will need to be established. Manuals will need to be produced that cover the installation of road heating systems and anti-freezing pavement as well.

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